UNIVERSITY OF COLORADO SEMICENTENNIAL SERIES
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Vol. I. The Natural Resources of Colorado

Vol. II. Colorado Plant Life

Vol. III. The Zoology of Colorado

Vol. IV. Colorado: Short Studies of Its Past and Present

Vol. V. The Creative Intelligence and Modern Life

UNIVERSITY OF COLORADO

SEMICENTENNIAL PUBLICATIONS

Authorized by the Board of Regents of the University of Colorado and prepared under the supervision of a committee of the Faculty consisting of William R. Arthur, George F. Reynolds, Oliver C. Lester, Herbert S. Evans, C. Henry Smith, and Maurice H. Rees, these five volumes are issued as part of the celebration of the Semicentennial of the University, November, 1927. They will be of interest primarily to the people of this State and are appropriately

DEDICATED TO

THE CITIZENS OF COLORADO

COLORADO PLANT LIFE

BY

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PREFACE

Rough granite hills and mountains, scattered pine trees, railway trains puffing prodigiously as they make their way, now to right now to left, up crooked canyons; automobiles crowded upon narrow and dangerous highways, summer hotels, rodeos, trout fishing:—all this is Colorado to the summer vacationist. To one who knows something of the world of life there is much more. Animals and plants are always interesting to those acquainted with them, and there is no part of the world outside of the tropics having more of biologic interest than the Rocky Mountain region. The chapters of this book deal with plants; the trees, the grasses, and the flowering herbs of the State of Colorado.

An attempt is here made to present in simple form some of the larger facts of plant life for the man or woman who is not trained in botany but who wishes to gain an appreciation of nature. Care has been taken to make all statements accurate, and it is hoped that the book will not seem shallow just because it is non-technical.

Considerable original material, based upon accurate field studies during many years, is here presented for the first time. The half-tone illustrations are chiefly from my own photographs. The drawings of plants have been made by me or under my direction.

A number of my associates on the Faculty have kindly looked through parts of the manuscript: Dean Oliver C. Lester, Professors T. D. A. Cockerell, Junius Henderson, Philip G. Worcester, Severance Burrage, Walter C. Toepelman, Miss Norma LeVeque, and Mr. Paul Franklin Shope.

Dr. Edna Louise Johnson has made a painstaking examination of the entire manuscript and has suggested a number of improvements.

Two or more chapters have been examined by each of the following: Darwin M. Andrews, Miss Katharine Bruderlin, Miss Alice Endicott, Arthur T. Evans, George D. Fuller, Herbert C. Hanson, Miss Ada Hayden, Arthur E. Holch, Miss Olive M. Jones, Miss Helen Arvilla Leonard, Arthur C. McIntosh, Aven Nelson, L. O. Overholts, C. William Penland, Miss Maxy Alice Pope, Ed. L. Reed, W. W. Robbins, Miss Glenn Stiles (now Mrs. Lorin B. Alford), Miss Marion Stilwell, Arthur G. Vestal.

The kindness of the Committee on Semicentennial Publications, has done much to make the burden of the preparation of this book lighter than it would otherwise have been.

The originals for the three colored plates were made through the courtesy of Professor John W. Rennell of the Department of Art who enlisted the expert services of Miss Muriel Sibell, Instructor in Art, whose work speaks for itself.

Professor Edmund W. Sinnott and the McGraw-Hill Book Co., have kindly permitted the reproduction of a number of figures from Sinnott's "Botany: Principles and Problems".

To all who have helped in any way I wish to express my gratitude.

* * * * * * *

More than to all others I am indebted to my parents; to my father, David Ramaley (1828-1914), in whose company as a child and youth I took long walks through woodland and over prairie and learned to know and enjoy the beauties of the world of nature, and to my mother, Louisa DeGraw Ramaley (1838-1922), ever interested in the intellectual life, who would often read to me for hours together when, as a student, my own eyes failed me.

F. R.

Boulder, Colorado,
August 1, 1927

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PLATE I

Chapter 1

PLANT SOCIOLOGY

People must adapt themselves to their surroundings if they are to prosper and be comfortable. Else they must seek another location which is more suited to them. The Eskimo of the far north would find the climate of the city of Washington not at all to his liking. The people too would be uncongenial. Putting this into scientific phrase, it might be said that the Eskimo would be in the wrong environment, both non-living and living. In his own home, however, he fits into his proper niche, and all is well.

Struggle for Existence

All living things exhibit a "struggle for existence." In human society, if there is an overplus of workers in a given occupation there results a struggle for employment. The poorer workman must either take lower wages or fail to hold his position. Sometimes he finds it best to move to another town or else to engage in some other kind of work.

Just such experiences come to animals and to plants. If there are too many of one kind in a given place, some will be poorly nourished and many will die. If climatic changes occur, many plant species either die out or must migrate. Slow movements of plant populations occur whenever the climate becomes permanently warmer or colder. Plants of the ice age in Colorado moved up the mountains when the climate became more mild. Those of the foothills went to mid-mountain districts, while the montane plants went still higher. But any pronounced change in climate, whether a lowering or raising of temperature, results in the death of countless thousands of plants and animals and the complete destruction of all the members of certain species. Likewise, severe pestilence may at times bring to extinction various species of animals or whole tribes of human beings. It is only those species which are suited to the environment that can survive.

Plate I. Plants of Marshes and Wet Meadows. *A*. Little-Red-Elephant (Elephantella); *B*. Brown-eyed Susan (Rudbeckia); *C*. Arnica; *D*. Shooting-Star (Dodecatheon); *E*. Chiming Bells (Mertensia).

A forest exhibits very well the struggle for existence. At first, when all the trees are small seedlings, there is no competition. Sunshine and water and soil there are a-plenty,—enough for all. But, as the trees grow larger and spread out, a crowding occurs. Here and there certain trees grow faster than the others, either because of greater natural strength or perhaps because of a better place for their roots. Soon overtopping the rest, they cut off the light, and many of the weaker ones succumb. The fittest, or else the more fortunate, survive; others are killed by unfavorable conditions.

A desert or arid waste exhibits a different kind of struggle for existence. No great number of plants can ever get a foothold, so there is no crowding. The plant has no struggle with its fellows nor even with other kinds of plants. Its foes are found in the lifeless environment, the rocks, sand, burning heat, and drying wind. Clumps of sagebrush with wide pathways between, almost no grass or other herbs, bare ground showing plainly everywhere, tell the tale of hardship and struggle. Only the most hardy—the fittest for this particular environment—can withstand the strain.

Ecology; Plants and Their Environment

The study of plants in their relation to the environment is plant sociology, or ecology; in the whole field of botanical inquiry no study is more interesting. Ecology treats of such subjects as climate in relation to plant growth, soils and their value for plants, the competition of plants with plants, and the relations which plants bear to animals. It is easy to realize that this may be a worthwhile subject, since the environment looms large for plants, just as it does for men.

Many ecological questions which even a child might ask have never been fully investigated. It is not easy to explain why some plants blossom in June, others in July, and still others in August. Reasons are not at once fully apparent for the presence of pines on the lower foothills and mesas, and their absence from the adjacent plains. Why one district is suited to peach growing and another to cherry culture, needs further study. Soil and climate must be largely responsible for the distribution of trees but just what influence each has, can not be stated with exact-

ness. Some canyons have many cedar trees, others quite near have very few. There are waterlilies in one pond but not in many another. Certain flowers have nectar which insects gather; others have no nectar yet seem to prosper quite as well.

Plants and Landscape

Plants make a large part of the landscape. Who can travel through the sagebrush and cactus of our western plains and forget the ever-present grayish-green of nature! The scenery of the Mississippi Valley is made by the meadows and groves, and these depend upon climate and soil. New England hills aflame in autumn with the red of maple and sumac are the same hills which appear dull and brown a few weeks later. Winter's brown on our great plains changes to vivid green in springtime. The poppy fields of California are now yellow, now green, now dull and lifeless. All of these interesting landscape modifications are due to changes in the plants.

Plants and Their Names

It is a common view that botany is the study of the names of plants, but there is much more to be studied than names,—much that is far more interesting. If one wished to know the names of all the plants of the State and could learn one name each working day it would require about eight years for the flowering plants alone. Besides these, there are probably almost as many non-flowering plants: algae, fungi, lichens, liverworts, mosses, ferns, horsetails, clubmosses. But one may find an interest in plants without knowing them all by name. Much satisfaction comes from a study of the plant itself in its natural surroundings, its season for flowering, the particular nook or corner which it is able to secure for its abode, its usual plant companions, and all the other features of its everyday life.

Adaptation

Many of the facts of plant distribution and some of the facts of plant structure are related to environment. The flora of alpine heights, discussed in another chapter, affords an illustration. Under the austere climatic conditions of mountain peaks very few plants can grow. Such as can exist there often show peculiarities which fit them to their surroundings. But it need not be

FIG. 2. Yellow Waterlily in Red Rock Lake, near Ward, Colorado. "Pond-lilies with long leaf-stalks and broad leaf-blades fit well into their particular place in nature."

forest these birches would surely die. Sunflower plants would, in the same way, be quite unable to exist in the cold soil of sub-alpine bogs of mountain heights. They must have warmth, and a soil not too wet. They can not adapt themselves to other conditions.

But someone may ask: "Is there then really no such thing as adaptation among plants?" The full answer to this would be a long story. It may be enough to say that the flora, or general plant population, of any locality may be "adapted" to a locality through the survival of certain species and the killing off of others. Sand dunes, wherever they occur, are all much alike so far as the appearance of their plants is concerned. This is because only plants of certain general types or habits of growth can continue to live in shifting sand. Such plants may occur on hillsides or along roadways or sandy streambanks almost anywhere, but not in abundance. Some of them may happen to get started on a sand dune where there is no competition for space; there these "sand dwellers," soon grow apace. Thus the general flora of the sand dunes shows an adaptation to its peculiar environment, although the individual plant species have not been altered by the conditions under which they grow.

Ecological Classification of Plants

A useful ecological, i. e. sociological, classification of plants may be based upon their relations to water. Thus, there are *hydrophytes*, plants living in water or in bogs; *xerophytes*, those of dry soil; *mesophytes*, the plants of soil with a medium amount of moisture. These terms are self-explanatory to the classical student. The Greek root *phyte* means "plant" and the literal meanings of the three words are then "water plant", "dry plant", "medium plant".

Hydrophytes

Hydrophytes in the Rocky Mountain region are found in streams, irrigating ditches, lakes, reservoirs, and pools. Various pond scums, water-silks, diatoms, and other simple plants occur in nearly all fresh waters. A certain kind of moss grows submersed in running streams. Pond-lilies flourish in some of the higher mountain lakes in which the soil of the lake floor has an abundance of vegetable matter, or humus. In shallow lakes there are pondweed, bur-reed, and bladderwort. Lakes in lower

altitudes are often surrounded with cat-tails and bulrushes. These two last-named plants are, however, not altogether hydrophytic, for they are so constructed as to conserve water as do true xerophytes. Most of the hydrophytes here mentioned are familiar to those who have lived in the eastern United States. If not known by name, their appearance, at least, is familiar.

Hydrophytes often show certain peculiarities of structure which make them well suited to their environment. They look as if intended to live just where they do live. No one would

FIG. 3. Oregon-grape. A holly-like low shrub with yellow flowers in early spring and dark blue berries later in the season. The leaves are thick and tough. They remain green all winter.

imagine lilac bushes or sunflowers to be pond or marsh plants. They do not have the appearance or form of plants intended by nature for such places. Pond-lilies with long leaf-stalks and broad leaf-blades fit well into their particular place in nature. Bur-reeds, with slender, grass-like leaves floating or submersed, are not injured by waves or currents. Bladderwort leaves, much dissected into narrow strands, are not in danger of injury from storms, because they expose so little surface to the waves.

XEROPHYTES

Xerophytes, the plants of dry situations, exhibit a number of interesting features, some of which are of evident advantage in bringing the plant into harmony with its environment. (See Plate III.) Since xerophytes grow in dry soil they need to conserve all the moisture they can get. Such saving of moisture can be brought about in any one of a number of ways. Leaves may be very small, as in pine trees, thus reducing the amount of surface from which evaporation may take place. Leaves may be fleshy and full of water, as those of the stone-crop. There may be a thick waterproof cuticle which keeps the leaves and stems from drying up. Kinnikinik and Oregon-grape (Figs. 1 and 3) show examples of this. A development of hairs on the stem and leaves acts as a screen from the bright sun and saves moisture. Sagebrush has this means of protection. Yarrow also, and various alpine plants, and dozens of plains species as well, are protected in this same way. These plants appear whitish or bluish in color. Arid districts have a pale green appearance in their vegetation, a condition familiar to all dwellers in the West.

Prickly-pears and other cactuses are especially suited to dry conditions. Their leaves are reduced to spines or scales so that there is very little evaporating surface. The swollen stem is flattened in some cases, thus displaying a moderate amount of surface to the sunlight for purposes of nutrition and proper growth. Much water accumulates in the stems; the roots grow down into the moister layers of soil, sometimes ten feet or more.

From these examples, it is seen that there are various ways in which xerophytes meet the dry conditions in which they are placed. Some have one method, some another. Certain species adopt a number of different methods in solving the problem. Many swamp plants are really xerophytes; they can get little water from the cold soggy soil and would die if they did not have the thick epidermis and reduced leaf surface which limit water-loss.

MESOPHYTES

Mesophytes are plants living in conditions of medium moisture. They have no special structures to adapt them to moisture conditions. (See Plates I and II.) They show all kinds

of roots, stems, leaves, and flowers. Certain species may exhibit some hydrophytic characters or even xerophytic structures. They form a mixed assemblage of almost every description.

Cultivated plants are mesophytes. Indian corn, wheat, cabbages, beets, roses, and all ordinary shade trees such as maple, elm, and cottonwood are examples. Besides these, meadow plants and plants growing anywhere in good soil are mesophytic. The eastern and southern parts of the United States are, in general,

FIG. 4. Meadow Rue. A plant of moist thickets; leaves divided into many leaflets; flowers small, green and inconspicuous.

regions of mesophytic vegetation. There are local areas of poor soil in which only xerophytes flourish; sand barrens, ridges, bluffs, and railway embankments are not suited to a mesophytic flora. In the Rocky Mountain region the native mesophytes are restricted to streambanks and lake margins and occasional seepage areas, except in sub-alpine districts. In such high altitudes there is greater rainfall than lower down and also less evaporation because of the decreased temperature.

Differences between mesophytic plants which grow in the sun and those which grow in the shade are often striking. The same species of plant, if sufficiently plastic, may occur in both habitats. In this case the shade plant is likely to be brighter green, taller, and less hairy. The leaves are thinner and often larger; leaf-stalks and flower-stalks are longer. A good example of these differences is seen in dandelions from sunny and shaded places.

Some plants grow always in the shade. Most ferns are examples; meadow rue and water-leaf are also typical shade plants. In these particular plants and in many others which are confined to shady places the leaf is much divided. It is highly compound, with very small leaflets which catch best the little sunlight which filters from above through the leaves of trees and shrubs. (Figs. 4 and 5.)

Just as there are shade plants, so also are there sun plants. Many are known to everyone. Perhaps the sunflower first comes to mind, but roses, asters, and chrysanthemums need all the sunshine they can get. There is no special form of leaf which belongs to sun plants, the true sun dwellers have leaves of moderate size and moderate thickness.

PLANT ASSOCIATIONS

In becoming acquainted with the plants of a region it is best to observe the associations in which they occur. By the term "plant association" is meant a group or community of plants growing together under like conditions: as the plants of an aspen grove, of a spruce forest, of a sagebrush flat, or of a mountain meadow. Plants thought of as members of associations become much more interesting than when considered as mere individuals.

Distinct advantage may result to plants from association with others. A single moss plant would soon die: it would dry up and wither in a short time. So mosses form societies and grow in small tufts or large patches. In such numbers they protect the soil from drying and they form a sponge which absorbs even the slightest rain or dew; thus the plants are always moist.

Pines, spruces, and firs are social plants. They need the protection afforded by other individuals and thrive best when growing in large numbers together. But not only do these plants

form associations themselves but other plants are included with them. On the floor of the Engelmann spruce forests in the mountains of Colorado, blueberry bushes grow in abundance, and they are not to be found in the open. There is just enough shade, and the soil is kept cool enough and moist enough. The blueberries thus enter into the community of spruces, as associate members, so to speak, participating in the benefits of the society but having no voice in its management.

FIG. 5. Water-leaf. A plant of moist and shady places. The small, whitish clustered flowers have long and conspicuous stamens.

In the plains regions there are many kinds of plant communities, formed chiefly of one or another kind of grass but with different flowering herbs intermixed. Usually each type of soil has its own special assemblage of plants. So it is on mountain sides, or in valleys; each environment supports an appropriate plant association.

A knowledge of climatic and soil requirements of different plant communities can be made use of in determining the sort of

crops which may be grown on any particular piece of land. Certain wild plants suggest that the land may be used for wheat; other plants are "indicators" of garden land; others show that the land will serve best for grazing.

Plants of Poor Soil

Plant communities of poor soil might be thought to exist in such soil because conditions suit their needs. This is not always true. A plant may grow in a poor place simply because it is not able to secure a better location. No man would willingly select a dark and crowded tenement house for a home. He takes it because he can not pay the high rents asked for better dwellings. He is crowded out of good society by those who are stronger, by those who have more money in this particular case. The poor mountaineer of Tennessee is not a mountain dweller just because of any special hardihood or love of the mountains, but rather because he is unable to compete with the more energetic men of the lowlands. So, many plants occur now only in the mountains because crowded out from good surroundings by stronger species which are better fighters. Such plants as knot-grass and shepherd's purse, seeming to choose the dry, hard-baked soil of roadsides, merely establish themselves there in unoccupied soil. Indeed, they grow larger and with more luxuriance in an unweeded garden. But they can grow in poor and dry soil and they do so, for they find there little competition.

Altitude and Plant Distribution

Some kinds of our native plants are able to grow in almost any climate within the State. Thus, the common yarrow is a weed along roadsides in the plains country and extends almost to the tops of alpine peaks, where it grows in either dry or wet soil. Stone-crop is another plant found all the way from the lowest foothills to the mountain tops. There is no great difference between specimens on the mesas near Colorado Springs or Boulder and those at an altitude of 10,000 feet. In higher situations, the stone-crop may become much dwarfed but it is still successful in holding its own. Shrubby cinquefoil grows in moist soil from 6,000 feet to timberline; the limber pine has the same altitudinal distribution but it occurs on dry wind-swept ridges. These two plants, although in the same geographical

localities are not found side by side. They grow in different soils.

Certain plants have a very restricted range. Thornapples, or hawthorns, in Colorado, belong to the foothills and do not grow on the plains or in the high mountains. There are, it is true, thornapples in Nebraska and Kansas but these are of different species from those of the Rocky Mountains. For each kind of thornapple in Colorado the distribution evidently depends much upon temperature, for since these trees grow along water courses there is surely no difficulty in getting the necessary moisture. The Colorado blue spruce, our state tree, is found wild only in canyons and parks of the upper foothills. It is never seen at high altitudes, and it grows in the plains region only when planted there and irrigated.

The ranges of limber pine and shrubby cinquefoil suggest certain conditions in human society. Thus, in all our large cities there are Caucasians and Mongolians. Both seem suited to the general conditions. Their geographic range is the same, yet they do not occur together. They live their lives apart. The same condition exists with whites and negroes in many places. In the study of plants, one comes again and again into contact with basic principles of sociology,—but so dehumanized that they can be viewed without prejudice. Since there need be no bias in the study of plants—no Democratic, Republican, or Socialistic ways of viewing nature—it would be highly desirable if everyone could get an introduction to sociology through a study of plants.

RELATION TO ENVIRONMENT

Plants are known by their surroundings and by their companions. They do not grow in different situations in a mere hit-or-miss manner. Their distribution depends on soil, temperature, moisture, wind, other plants, and animals. To know a plant is to know it in all of these ecological relations quite as much as to be acquainted with the size of its leaves, the height of its stem, or the color of its flowers. A man is known, not merely by his size, shape, and color; his business, his family relations, the company he keeps, the clothes he wears, the house he lives in, all are a part of the man. So with a plant,—the

environment limits it, conditions it and fixes many of its qualities. The keynote of the essays which form this book is *relation to environment*. It is from the ecological standpoint chiefly that a reason and a meaning is to be found in the plant life of any geographic area.

Chapter 2

LIFE ZONES AND ALTITUDE

In Colorado, and in other mountain states, one hears much about altitude, while people of the lowlands hardly know the word at all. Probably the average citizen of Chicago or Buffalo or St. Louis or St. Paul has very little idea of the height above the sea of his particular city. Every dweller in Colorado, however, knows the altitude of his own town and probably can tell something about the altitude of a number of other places in the State. (Fig. 6.)

The greater part of the human population of Colorado lives from 4,500 to 6,000 feet above the sea. With the exception of mining towns such as Cripple Creek and Leadville, both above 9,000 feet altitude, there are no large communities in the high mountains. This is to be expected, for the climate of the higher places is severe.

The larger part of the plant population of Colorado also is at the lower elevations, since there the climate is not too cold. There are greater areas of good soil for agriculture and not so much gravel and rock.

It is well known that plants of alpine heights are small and have proportionately larger flowers than those of ordinary situations. People who have been in the mountains know also that the same kind of plant will blossom at high altitudes later in the season than at lower stations. These facts are generally accounted for by "altitude" in a loose way.

Altitude and Climate

In what manner does altitude affect plants? Is it through thinness of the air, or by lack of moisture in the air, or by cold, or wind, or soil dryness? Are the rays of the sun too bright? Is it too often cloudy? Is the slightly smaller percentage of carbon dioxide at high elevations of consequence? Are there differences in the ultra-violet rays which reach plants through the thinner air of high districts?

Doubtless the rarity or thinness of the air, i. e. low air pressure, comes first to mind in thinking of mountain conditions. Rarity of air permits water to boil at low temperatures. As is

well known, it takes a long time to cook eggs on Pike's Peak by boiling. They boil easily but do not cook. In the rarefied air, breathing does not satisfy, and a person easily becomes "winded" with slight exertion. But these are hardly matters of consequence to plants. The slight difference in amount of carbon dioxide is probably of no moment, nor is any variation in the ultra-violet light. The effects of altitude on plants are evidently indirect; they come chiefly through lowered temperature and short seasons, high winds, and active transpiration (water evaporation).

Each one-thousand feet of altitude above the sea makes a difference of about three degrees in temperature. Thus, if people in Denver are fanning themselves and trying to keep cool in a temperature of eighty in the shade, the camper or fisherman in the mountains at Grant will find it cool and pleasant even for strenuous exercise, since he is 4,000 feet higher and is enjoying a temperature of sixty-eight. Of course, it must not be supposed that this temperature difference of three degrees to the thousand feet is a constant one, but it may be taken as representing the average effect of altitude.

The mean temperature for July is a good indicator of climate. This is at Denver (5,275 feet) 71.8 degrees, at Corona (11,660 feet) 47 degrees. The true significance of these figures is brought out by comparison with various northern localities: New York City 74, Chicago 72, Duluth, 66 degrees.

Annual rainfall, which is so low on the plains as to make the climate semi-arid (Denver, 14 inches), reaches about 32 inches in the mid-mountain districts and is 44 inches at Corona, on the Divide above the Moffat tunnel. Figures from other points named in the preceding paragraph are: New York City 45, Chicago 33, Duluth 30 inches.

Environment and Plant Life

Plants reach greatest luxuriance in the tropics where, in addition to high temperature, there are to be found wet soil and humid atmosphere. On mountain summits of the Rockies the opposite conditions prevail. The air temperature is low every night in the year. Little water vapor is present in the atmosphere during most of the day. The soil is never warmed except for a few inches at the top, and roots have difficulty in their work of

absorbing moisture. The soil, because of its low temperature, is physiologically dry even though actually it may be well supplied with water, for the plants can not make use of the water which is present in the soil. Soil temperature one foot below the surface in open grassland near Denver averages about 68 degrees Fahrenheit during July; at Tolland, Colorado (altitude 8,889 feet) it is 64 degrees; in sub-alpine districts (altitude 10,500 feet) the temperature is about 60 degrees. Together with the difficulties caused by cold soil, the high winds have a drying effect, and the

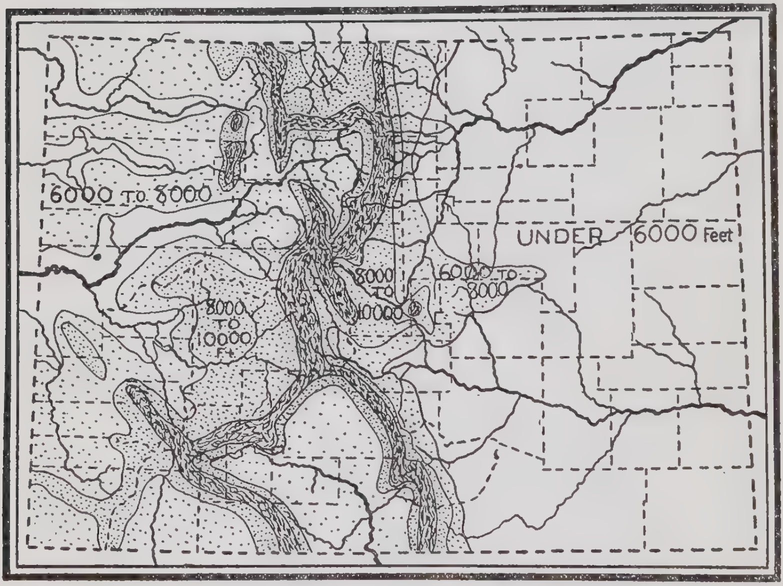

Fig. 6. Map of Colorado, showing elevations above sea level.

blistering rays of the sun at mid-day furnish an extreme of heat which is not favorable. As the result of all these conditions there is but a sparse population of plants in high altitudes. Only such plants are able to live there as can grow rapidly during the short summer, and mature their flowers and fruits before cold weather. They must be of such structure that they will not be dried up by wind or killed by cold. If plants of other natures should get started on a mountain top they would not survive. They would be eliminated as "unfit," in the language of the biologist.

The direct effect of low air pressure on plants has been studied by various investigators in laboratory experiments and it appears that this is in no way like that of high altitudes. When plants have been cultivated in glass cases from which part of the air is exhausted they grow much more rapidly and attain a greater height than plants at ordinary air pressure. It is evident, therefore, that the diminished air pressure is not responsible for the small size of plants in alpine heights.

Dryness of soil and air, as is well known, and also intense light, low temperature, and short summers tend to induce dwarfing of plants. Hence, if the dwarfing be caused by environmental factors, these are the ones to be considered. The author feels, however, that the environment does not really cause the "alpine" habit of most plants in high altitudes. Some species of plants show two different forms, the ordinary and the "alpine," and these may be found growing close together, but in different soils. In such cases, it is evident that the soil conditions are the cause of the difference. Then again, certain plants when moved from well-drained soil to cold, boggy ground become much changed, so much indeed that they resemble other natural species. Among most "alpine" plants, however, all of the individuals of a species have about the same growth-form, whether on the tops of mountains, or in forest openings, or cultivated in a garden at ordinary altitudes. The mountain forget-me-not (Fig. 7) is of the dwarf cushion type because of its real nature, and when planted at moderate altitudes it keeps to its usual form if it can be made to grow at all.

The importance of dryness of soil in bringing about dwarfing of individual alpine plants is not generally appreciated. Much of the soil of mountains is a coarse gravel and sand, formed by the disintegration of granitic rock. This dries out quickly. Even the daily showers of summer, which are likely to occur in the mountains, fail to keep such soil moist. There are, it is true, some places in the high mountain districts where finer materials of rock weathering have collected in cracks and crevices, protected from wind and from too brilliant sunshine. In such places, plants may grow to a good size, and have a different appearance from the stunted specimens of exposed habitats. But this is true only of certain few species. The "alpine" growth-

form (Fig. 8, Mountain Pink) is as much a part of the usual alpine plant as are its flower color and leaf form.

The so-called "alpine" habit is not confined to mountain plants but is seen also at lower altitudes; certain kinds of phlox, mountain daisy, and butterweed of the foothills have the leaves in a rosette, the stem short, and the root large.

The thin air of mountain tops does not long retain heat, so with the close of day comes sudden cold. Even at mid-day it is cool in the shade. The sun's rays are bright because they are not impeded by heavy atmosphere; where the direct rays of the sun

FIG. 7. Mountain Forget-me-not (at left). An alpine mat plant with flowers of purest blue.

FIG. 8. Mountain Pink (at right). An alpine plant of dense cushion type, typical of the dry tundra.

fall, the light and heat are intense. Alpine plants are thus in an austere environment.

True alpine conditions exist only on the tops and sides of mountains. At the bases of the mountains, even though the altitude be 11,000 feet, conditions for plant growth are rather favorable. Here, due to the melting of snow fields above, there are large areas of moist ground. Small lakes and marshy meadows occur, and there are dense forests of spruce and fir. There is much less wind than on the peaks; plants do not lose water so rapidly. Some of the plants are like plants of the Eastern States.

The student of plants who would seek in Colorado such wild flowers as those of his eastern home must go where conditions permit their growth. If he does visit these sub-alpine districts he may find a few species identical with those farther east and still more which, though not identical, are similar.

In all the mountain areas, the growing season is much shorter than in the lowlands. Most plants do not begin to grow in the spring until a temperature of about 40 degrees Fahrenheit is reached; it is barely so warm as this in Denver during March days. So it will be about three degrees colder at a point 1,000 feet higher in the foothills. No growth will occur there until the temperature in Denver has reached 43 degrees; this may be one or two or even three weeks later, depending on the particular season. Thus it happens that the time for the appearance of the flowers is generally much later in the mountains than on the plains. Those plants which grow both in the lower foothills and at high altitudes show the effect of the different climates in their time of flowering. The mariposa lilies on the foothills near Denver are in their prime about the first of June. In the mountain parks they bloom during July, while at altitudes of 9,000 and 10,000 feet they are most abundant in August.

One sometimes hears the statement that plants grow smaller and smaller as we ascend the mountains until they are short and stemless, lying upon the ground. It is quite true that some species of plants found regularly at medium altitudes are represented by short, dwarf specimens in higher places but this is not always the case. The columbines found at 10,000 feet are just as fine and as tall as those from the foothill districts, and the same may be said of many other plants. It is true, however, that columbines on the mountains close to timber limit are usually dwarfed. Generally it is the case that alpine plants are smaller than plants of the lower mountains but, with a few exceptions, they are different species. Indeed very few species which grow in the alpine heights occur down in the lower mountains and foothills.

A species of plant which grows at stations between 6,000 and 10,000 feet will seldom show any great diminution in size of individuals until near the upper limit of its range. Close to the upper limit there may be both the ordinary form and the dwarfed

form, perhaps growing a few feet apart. In such cases the small plant is found in dry or poor soil. Hence the altered climate of

FIG. 9. Pasque Flower. An early spring flower abundant in the foothills and extending through the montane zone, occasionally even to timberline.

the high altitude is not alone sufficient to produce the "alpine" appearance in the plant. This climatic influence must be reinforced by soil dryness.

The effect of altitude on plants is the combined effect of low temperature of air and soil, low relative humidity, and brilliant sunshine. Individual plants do not, as a rule, assume special shapes because of these conditions, but species of plants which naturally grow tall or have large leaves would not find on the alpine summits suitable conditions for their growth, and hence they do not occur there.

DIFFERENT KINDS OF PLANTS AT DIFFERENT ALTITUDES

Much popular misconception of alpine conditions comes about through natural differences in flora of low and high altitudes. Colorado has climates which are as unlike as those of Italy and Spitzbergen. It is natural that the plants should be different in these climates. But this is something that is not always remembered. If a sulphur flower is seen on the plains at Denver and another similar flower is found on Mount Evans, people think that the two are plants of the same species altered by differences in altitude. But this is not true at all. They are distinct things just as different as are the arctic fox and the common red fox of warmer countries; just as different as are the negro of Africa and the white man of Europe. It is not the climate that makes the negro black, the Indian red, and the European white. Moved from one continent to another they remain the same as they were in their former home. This is well seen among Americans, who have not become copper colored, and among the Australians who have not taken on the black of the aborigines.

CULTIVATION OF ALPINE PLANTS AT LOWER ALTITUDES

In many cases, if alpine plants are moved to lower stations they remain practically the same in structure as they were in their original home. Others refuse to grow in the changed environment. A few only will become altered to a form resembling lowland species. The great majority of alpine plants then are not altered plants of lower altitudes but are distinct species just as the species of Greenland are different from those of South Carolina.

THE REAL FACTS OF ENVIRONMENTAL INFLUENCE

The principal effect of altitude upon plants is to limit their geographical distribution by affecting climate. Arctic and sub-

arctic forms find a congenial home on the mountain tops; plants of the cold north find conditions similar to those of interior Alaska or the Hudson's Bay country if they grow in Colorado at 10,000 or 11,000 feet altitude. There are sorted out for each altitude those species which do best in the climate determined by that altitude.

It must not be thought that the alpine climate makes the forget-me-not or the arctic poppy small. These plants are naturally small and low. Hence they are able to withstand the unfavorable conditions of alpine heights.

There is no good reason for thinking that plants develop useful permanent structures in response to climate. If useful changes in plant structure become developed through variation or otherwise it is likely that the plants thus modified will survive and perpetuate their kind. So, in the course of long ages, the plants of a region will *appear* to have adapted themselves to particular surroundings. But what has really occurred is a killing off of all species not well fitted to the environment. Altitude, with its accompanying differences in climate, does not change plants themselves, it merely determines where any particular species can grow.

Life Zones

If a traveler should go from the equator to the north pole he would find the character of the vegetation changing greatly along the way. Sometimes there would be gradual transitions; it would be only in many miles of travel that any great change would be noted. At other times the alterations would be more abrupt, as in passing from forest to prairie or from an area of great rainfall to one of dryness.

The regions traveled over, might be classified into certain vegetation zones and districts; in tropical lands: rain forest, deciduous forest, savanna, and desert. In the temperate zone there are areas of greater moisture and heat followed by those which are cooler and drier. In the arctic and sub-arctic regions very special conditions prevail and the vegetation is of a kind to correspond.

An isolated mountain, if sufficiently high, shows definite zones of vegetation depending on the climatic differences at lower and higher elevations. The botanist Schimper names

three zones, the *basal*, the *montane*, and the *alpine*. Plants of the basal zone resemble those of the moister parts of adjoining lowlands; plants of the montane zone are like those of lowlands in more northern parts of the world; plants of the alpine zone are similar to arctic and sub-arctic forms. This classification of zones is a general one, not made by the study of any one particular mountain, but seems to represent conditions in many parts of the world. On a typical isolated mountain, such zones would be continuous all of the way around and would be somewhat symmetrical. The north exposure, however, would have the montane and alpine zones extending down lower, because there it would be colder, and the limits of the zones on the south slope would be higher because of greater warmth on that side of the mountain.

The Rocky Mountains do not rise from lowland country but have their bases 5,000 to 6,000 feet above sea level. The plants of the lower foothills, except those of canyons and draws, have very little more moisture than comes to the plains. In the foothills—5,000 to 8,000 feet—the vegetation of hillsides partakes largely of the dry-country type; it is more nearly related to dry plains than to moist lowlands. The vegetation of canyons, in contrast is much like that of moderately moist open situations of higher elevation.

Temperature and soil moisture, as previously indicated, are the chief factors of altitude which influence plant distribution. At the higher levels there is the greater rainfall and the lower temperature. These climatic influences have their inevitable effect on the plant life of the region. Hence arise the zones of distribution, so well known to the botanist and so easily recognized by all who travel in various altitudes.

Since the classification of Schimper does not fit exactly the conditions in the Rocky Mountains, it will be worth while to substitute another which will express the facts as they exist. The author has elsewhere proposed the following, which applies best to the eastern slope of the Rocky Mountains between Denver and the Wyoming line. Five zones are distinguished: Plains zone, up to about 6,000 feet; Foothill zone, 6,000 to 8,000 feet; Montane zone, 8,000 to 10,000 feet; Sub-alpine zone, 10,000 to 11,500 feet; Alpine zone, 11,500 feet and higher.

THE SEVERAL LIFE ZONES OF COLORADO

The plains are, of course, those areas east of the foothills where there are no trees, except along water courses, or on bluffs and ridges.

Foothills and mesas begin at about 6,000 feet, or a little lower. They have a sparse covering of rock pines on drier slopes, with Douglas spruces in moist places. The foothills bear an open forest with extensive stretches of grassland. (Fig. 10, Alternating Forest and Grassland.)

A denser forest is characteristic of the montane zone. It may be a mixture of rock pine and Douglas spruce toward its lower limit, and of Engelmann spruce, limber pine, bristle-cone pine, and sub-alpine fir in the upper parts where it adjoins the sub-alpine zone. In areas where fires have interfered with the original vegetation, a close stand of lodgepole pine often marks the montane zone. There are some extensive groves of quaking aspen and many open "parks". (Fig. 11, Park Landscape.)

The finest forests are in the sub-alpine zone, where Engelmann spruce is most at home,—about 10,500 feet altitude. Trees of three or four feet diameter are frequent in the uncut forest. Some which were felled by lumbermen have been found, on counting the annual rings, to be 400 or 500 years old. The sub-alpine zone has, oftentimes, a considerable amount of limber pine. This grows on dry ridges, where it is always somewhat mixed with lodgepole pine, spruce, and fir. At the upper limit of the sub-alpine zone, the trees are reduced in size, and they form the characteristic sub-alpine scrub, or "wind timber", frequently mentioned elsewhere in this book.

In the alpine zone there are no trees, but, in places, dense, low thickets of dwarf willow. These form shrub-islands in the general grassland steppe or tundra.

Mention has been made of the trees of the various zones because they are most conspicuous and can be used easily for characterization. In the following synopsis of vegetation of the zones, trees are listed first, but other features of the vegetation are indicated.

SYNOPSIS OF VEGETATION OF THE FIVE LIFE ZONES

1. *Plains zone:* dry grassland, with an abundance of spring-blooming herbs; cottonwoods and willows along stream-margins, a few pines and cedars

on exposed bluffs. In this zone the ordinary field and garden crops may be grown. Warmer areas are suitable for peaches, melons, and tomatoes; apples, plums, and cherries are the "fruit trees" of most localities.

2. *Foothill zone:* open forest of rock pine; Douglas spruce on north slopes; considerable stretches of grassland in level places. In southern Colorado, many of the lower foothills are nearly bare of large trees, but support a growth of mixed shrubs. Apples and plums may be grown in warmer situations, and the more hardy vegetables and garden flowers throughout. California poppies, petunias, and calendulas do well. Many ornamental shrubs, vines, and trees can not be grown.
3. *Montane zone:* close forest of pine alone, or of spruce and pine; scattered aspen groves, some grassland in mountain parks and on drier slopes and summits. Hay and potatoes are the only crops, although in sandy spots it is possible to produce lettuce, carrots, spinach, and table onions. Pansies, calendulas, and English daisies are the best plants for the ornamental garden. The native columbines and larkspurs are also satisfactory.
4. *Sub-alpine zone:* close forest of Engelmann spruce and sub-alpine fir, with limber pine in more stony and exposed situations; "wind timber" at tree limit. Openings in the forest permit the development of "mountain meadows", with a growth of sedges, grasses, and flowering herbs. There is no agriculture or horticulture in this life zone. The wild grasses afford pasturage, during the summer, for cattle and sheep.
5. *Alpine zone:* grassland steppe, or tundra, and rock desert; various flowering herbs, some of mat and cushion form. There are certain areas of grass and sedges which serve as summer grazing grounds for sheep.

BOUNDARIES AND LIMITS OF LIFE ZONES

Study of the different zones discloses the fact that many of the shrubs and herbs correspond to the trees in their distribution. Hence the different zones suggested are not mere arbitrary conceptions; they depend upon real conditions and represent facts of nature. The grasses of the plains could not grow in the alpine heights because of the short season; many montane plants would find the plains too dry. Few of the up-country species could meet the competition which exists in lower altitudes.

The boundaries of life zones are sometimes made clear in the distribution of particular species. Many kinds of grasses which are abundant on the plains, reach into the foothill zone but go no farther. Some stop abruptly at the mountain front. Buffalo grass, which occurs in patches here and there on the plains near by, is seldom found in the granite foothills. Certain species of

sagebrush and of goldenrod are almost entirely confined to the plains region. Cat-tails and bulrushes also afford examples of this limited distribution, and do not pass to other zones. The limits of plain and foothill floras are marked also by the absence on the plains of certain plants which belong to the foothills. The pasque flower, or "anemone", as it is often called in Colorado (Fig. 9), is a good example. This plant ranges from northern Illinois, through Minnesota, the Dakotas, and Montana to the Rocky Mountains; then south in the mountains to Colorado and New Mexico. It is found in the montane and sub-alpine zones, but reaches its best development in the foothills. Here it is very abundant, forming the most interesting feature of the early spring flora. But it stops abruptly just short of the plains, and dwellers in the valley who have not been in the hills do not know it.

Many plants extend through two or more life zones but are most at home in some certain one. The columbine, which is the state flower of Colorado, is a montane plant, but it occurs sparingly in the foothills and extends up as far as timberline. Blueberries belong both to sub-alpine and montane zones, though they are somewhat more at home in the former. Elderberries are of the montane zone but here and there extend to higher altitudes.

If a stranger who had first been landed from an airplane in Denver, could be taken blindfolded to the east portal of the Moffat Tunnel, he would think himself a long way from Denver, for the general aspect of the region, and the plants are so different. Few of the species of plains plants seen at Denver extend so high as East Portal. Indeed, many of the genera are different. If the trip had been made to some point in the sub-alpine zone, say to 11,000 feet, still greater differences would be noted. Scarcely a single species of plant growing in the neighborhood of Denver would be found there, a point only fifty miles away. As much difference exists between the plains and the sub-alpine heights as between Virginia and Labrador.

In the montane zone, and above, the rainfall and snowfall are considerable. During some months of the summer almost daily showers occur and at times there are long continued rains. Snow is deep in winter, more particularly in the alpine and sub-alpine regions. It may remain as drifts in the timber late into June or even to July. Such drifts could not withstand the heat

FIG. 10. Alternating Forest and Grassland in the Foothill Zone. Pine trees on the ridges and grass in the fine-grained soil of the valleys.

FIG. 11. Park Landscape in the Montane Zone.

of foothills or plains and they indicate very plainly how cool it is in the mountains. The summer climate of the montane zone may be likened to that of Duluth or of northern Maine or the Adirondacks; summer in the sub-alpine heights is like the summer of the north shore of Lake Superior or the region of Hudson's Bay.

After a little experience in the mountains, one learns to know the altitude by the plants which are seen. This is, in fact, one of the most fascinating things about botanical study in a mountain region. All Colorado people are interested in altitude and if this can be told approximately by looking at the trees and other plants there is a great satisfaction to the observer. In making such observations one will need to know something of the plants of definite known elevations; then deductions for unknown points are easily made.

In judging of altitude by the plants seen, it will be best to keep in mind that those plants which grow in average situations, neither very wet nor very dry, furnish the best index to altitude. This is because low-country plants may extend far up on dry ridges while plants accustomed to moist soil in high altitudes often pass down a great distance along the streams, and occur at low altitudes in swamps or wet meadows.

It is possible to distinguish life zones for the United States just as may be done for Colorado, but the problem is more difficult. Whereas in the Rocky Mountains it becomes cooler with increasing altitude and at the same time more moist, if the United States be considered as a whole, the areas of low temperature and of great moisture do not coincide. It is warm in the southern part of the country and cool in the northern. These warm and cool belts are crossed by moisture belts at right angles. It is more moist near the coasts than elsewhere, while dryness becomes pronounced as the high interior of the continent is reached. This crossing of temperature and moisture belts leads to certain peculiarities in plant distribution. Many southern plants from Mexico and Texas extend north on the hot dry plains, while northern plants are able to spread far south along the cooler and more moist coast regions and mountain chains.

Just as the crossing of temperature and moisture belts results in various anomalies in plant distribution over the United States, so local conditions in Colorado at times bring about unexpected

results. Middle Park, which lies west of the front range, is an elevated district surrounded on all sides by mountains. Here the temperature, say at Sulphur Springs, ranges much lower than at the same altitude on the east slope of the great divide. Hence the zones of plant life are lower. Limber pine and Engelmann spruce are common at 7,000 to 8,000 feet altitude instead of 8,000 to 9,000 as they are across on the other side of the mountains toward Denver.

In steep-walled canyons a condition may exist which simulates that of open country at higher altitudes. The greater humidity of the air, and the coolness of both air and soil permit the growth of many species which are unable to live in dry, exposed situations. Sub-alpine fir and blue spruce which ordinarily grow not lower than 7,500 feet, sometimes come down in such places to 6,000 feet. Columbine and fireweed find in these cool, moist canyons the conditions which ordinarily exist at much higher levels.

Summary

While it is well to note the exceptional distribution of plants as has been done in the last few paragraphs too much must not be made of it. In the study of grammar, if attention is given to all of the exceptions to rules the student is likely to think that the rule is, after all, of no consequence. So here it may be well to state once more the general points made earlier. The effects of altitude upon vegetation are the effects of climate. There are zones of plant life which depend on climatic differences. These may be readily determined and characterized. In the Rocky Mountains these zones are best described by the names given; plains zone, foothill zone, montane zone, sub-alpine zone, and alpine zone. The vegetation seen in any locality tells much in regard to the climate of the place, its temperature and rainfall, and is hence an index of altitude.

PLATE II

Chapter 3

BOTANY FROM A RAILWAY TRAIN OR AUTOMOBILE

It is possible to gain some knowledge of the botany of Colorado from a railway train or automobile. The average person is not likely to go, on foot, into the woods or fields where close observation of nature is possible, but nearly everyone rides at some time through interesting canyons or along steep mountain sides.

A traveler who is alert of mind may learn something on even a one-day excursion. From Denver, there are such all-rail mountain trips as to Georgetown, or to the Moffat Tunnel, or automobile trips to Colorado Springs, Boulder, Estes Park, and Eldora. The Mountain Parks of Denver, and even Mt. Evans, can be visited by automobile in a single day, while it is possible to see a considerable part of the Rocky Mountain National Park in two days. From Colorado Springs, besides trips to the east, west, north, and south there is the one great trip upward to the top of Pikes Peak. In these sight-seeing excursions, there are not only the craggy summits, the deep gorges, and rushing streams but also trees, shrubs, flowering herbs, and grasses. And they have their story which those who will, may read and understand.

It is not intended to give a detailed account of what would be seen on any of the much-advertised excursions out of Denver or Colorado Springs. Such a statement belongs more properly to a folder issued by one of the business concerns engaged in transportation. The present chapter may, however, suggest some of the botanical features which can be noted in traveling through the plains country to the foothills and on up into the mountains, even when no stops are made for viewing the scenery or examining the trees and wild flowers.

Weeds

In going by railway out of any large city, one may become acquainted with those undesirable yet interesting plants known as

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Plate II. Plants of Hillsides, Meadows, and Forest Shade. *F.* Columbine (Aquilegia coerulea); *G.* Golden Pea (Thermopsis); *H.* Mountain Daisy (Erigeron); *J.* Mariposa Lily (Calochortus); *K.* Beard-tongue (Pentstemon); *L.* Cinquefoil (Potentilla).

weeds. At Denver, the railroad yards, especially to the north and west of the city, have a full assortment of these "plants out of place". Most of them are such as are common throughout the United States, but some are of more local distrubution. There are to be seen: the ordinary yellow-flowered dandelion of spring, the Colorado bee plant of midsummer, the evening-star with handsome creamy-white flowers appearing in August. Here, and elsewhere on any railway line, are found various members of the pigweed, goosefoot, mustard, spurge, purslane, and composite families together with numerous introduced grasses. Many are

FIG. 12. Pigweed (at left). FIG. 13. Russian Thistle (middle). FIG. 14. Shepherd's Purse (at right). These are all common weeds introduced from Europe.

of European origin, but some are from the eastern United States. (Figs. 12, 13, 14.)

The Russian thistle, which is not a thistle at all, and does not look like one, may be seen frequently from the railway coach or motor car. Russian thistles were hardly known in Denver before 1900, but in the period since that time they have become thoroughly established, flourishing with amazing vigor in vacant lots and along highways. The plants are two or three feet tall and quite unattractive in appearance, since the leaves and flowers are minute, and there is little to be seen but the straggling much-branched stems. Toward the end of the season, the branches

FIG. 15. Soapweed, or Yucca. An evergreen lily-like shrub of the plains and lower foothills. The large flowers are cream-colored.

seem to draw in, making a compact tumble-weed the size of a bushel basket. Easily rooted up, the tumble-weed is blown about by the wind, and as it rolls along, it scatters the seeds for another year's crop. Often great numbers of the plants are caught against a wire fence or a barn, and are thus stopped in their triumphal progress of seed scattering. It is possible that a good word could be said for the Russian thistle; but the appropiate word does not easily come to mind.

Many of the weeds in Colorado, as already suggested, are of foreign origin. They may not be especially troublesome or common in their native home, but here they find a larger amount of unoccupied ground in which they may grow and spread. About one hundred species of plants introduced within the State grow without cultivation. Among these, are Russian thistle, dandelion, mullein, mustard, couch grass, pigweed, and shepherd's purse. Not all of these will be recognized from a distance, but the first three, at any rate, are conspicuous.

Besides those plants which are everywhere called weeds, there are many less objectionable species from overseas. These other introduced plants, especially the grasses, make up, in some places, an important part of our present flora. There were no "weeds", however, when white men first came to Colorado. On mesas and hills of the eastern mountain border, where the original vegetation has been, in many cases, over-grazed and much trampled by cattle, the brome grasses are now abundant. Certain ornamental plants also, as "bouncing Bet", hollyhock, cosmos, and oxeye daisy are locally escaped from cultivation, and may be seen along roadsides. Clovers, sweet-clovers, and alfalfa grow wherever conditions are suitable.

Most of the introduced plants in the Colorado flora occur below 6,000 feet altitude, a few extend up to 9,000 feet, and practically not any are found in the high altitudes. The less elevated districts have soil and climate suitable for these plant immigrants, but the high mountains have a growing season which is too short and too cold.

Plants of the Plains

An interesting plant of the native flora, one likely to be noted at all times of the year, is the soapweed, or Spanish bayonet. It

grows especially on ridges and sloping ground of the plains country. The leaves are bayonet-shaped, and stand up from the ground in large bunches to a height of two feet. During late

FIG. 16. Large White-flowered Evening-primrose.

spring and early summer, when in flower, these plants are very ornamental because of their tall spikes of large cream-colored flowers; but in the winter they are really more conspicuous when little other vegetation is to be seen.

FIG. 17. Sand Lily. A low-growing white-flowered lily of plains and foothills.

FIG. 18. Prickly Poppy. A plant of the plains and lower foothills. The flowers are white, large and showy.

Various cactuses may be noted from a car window at any time of the year. Prickly pears are the commonest. (Plate III.) They have thick, flat, spiny branches about the size of a man's hand, the branches often being mistaken for leaves. The ball cacti are spherical, some the size of a marble, others as large as a baseball; but all very spiny and uninviting to the touch. In southern Colorado the tall candelabrum cactus has a grotesque appearance on hillsides and in railway cuts.

The plains do not always show the dull monotony which the name may suggest. They are often wonderfully varied in scenery. They are sometimes gently rolling, at other points sharply cut into mesas and buttes which are separated by deep gullies. Further than this, the different seasonal aspects of vegetation give the plains a certain variety. It is unfortunate that tourists generally see the plains in the brown of mid-summer rather than during May or early June when they are carpeted with green, and bright with the gold and purple of many blossoms.

In May, a striking floral display is produced by the low-growing and white large-flowered evening-primroses, often so abundant in fields and pastures. These are easily recognized without any stopping of the journey, for no other low-growing plant has large, white flowers each of four petals, the whole flower as broad as a woman's hand. These evening-primroses do not occur singly, and seldom even in small patches, but most often in hundreds of thousands. Other flowers of spring are numerous enough, but such small plants as bluebells or lungworts and Johnny-jump-ups are not likely to be seen while speeding on a journey. The sand lily, however, will attract attention, even though the flowers are not large. Sand lily plants have a short stem, entirely under the ground; the leaves are like those of iris, but scarcely as long as one's middle finger. Each plant may bear a dozen or more blossoms at one time, and when the plants are close together they can not escape notice. The individual flowers have long, narrow, white tubes with six spreading white floral-leaves. At the time of year when the sand lily is in blossom, the grasses and other vegetation are still small. The absence of other plants permits the gray-green leaves and pearly-white flowers of the sand lily to be conspicuous.

LOCO-WEEDS

In June, the traveler will see more loco-weed than anything else. "Loco" is not just one kind of plant; many kinds are called by the name. The so-called "Colorado loco-weed" belongs to the genus known to botanists as Oxytropis or Aragallus, but this does not define it exactly, for there are many species of the genus. The commonest and best known throughout the State as a whole, is a certain red-flowered species. (Plate III.) The leaves are of

FIG. 19. Colorado Bee Plant, or Cleome. Abundant in sandy soil of plains region. The flowers are pink.

many small leaflets, arranged in feather fashion on the leaf axis, and the cluster of crimson-red flowers rises from the ground about eight or ten inches. As the flowers fade they become bluish; this fact has led to a curious error in certain botanical works which describe the plant as having blue flowers. This results from using dried herbarium specimens in making the description. Another loco-weed is a rather tall-stemmed hairy plant with white flowers. It belongs to a genus very much like

Aragallus but with somewhat different flowers. Still other kinds of loco are of various size and flower-color. The true Colorado loco-weed is the best known because of its great abundance on plains, hillsides, and in mountain parks. It is not confined to Colorado but is abundant in Wyoming, Montana, and the provinces of Canada, often making the plains or prairies crimson at blossom time. In Colorado, the red loco blooms on the plains in June but in the mountain parks the flowers come in early July.

It may be of interest to note at this point that the loco-weed is thought to be the cause of poisoning to stock, especially horses. There has long been a general belief that these plants are responsible for a condition in animals known as "loco" in which there is great loss of weight and during which a frantic, or "locoed" (i. e. crazy) condition develops. Repeated tests by expert chemists failed to show the presence of any poison in the plant. It remained for the United States Department of Agriculture to make elaborate experiments to discover the facts. Many well-informed people even doubted that there was such a disease as "loco" and held that so-called "locoed" horses were really diseased animals suffering from various kinds of ailments. The results of experiments seemed, at first, quite conclusive. Animals after eating loco-weed showed the symptoms which have always been described by the name "loco." A more careful chemical analysis of the plants was then made, and although no vegetable poison was discovered the chemists found a minute quantity of the rare earth barium. Afterwards, when barium compounds were mixed with ordinary foods the condition of "loco" was said to be brought about in a previously healthy animal. At the present time this theory of barium poisoning is not taken seriously, and a satisfactory explanation of the cause of loco disease is yet to be presented.

Evening-primroses, Poppies, Cleomes, and Sunflowers

Reference has already been made to the white evening-primroses so common in abandoned fields on the plains. In the lower foothills, in mid-June the yellow-flowered dwarf evening primrose is often so abundant as to form a striking feature of the landscape. The blossoms are about three inches across, on short stalks close to the ground. When these flowers have passed

their prime the petals change through salmon-color to red. Somewhat distantly related to the evening-primroses are the evening-stars, rough hairy plants with flowers of many petals, yellow or white. (Fig. 20.)

The prickly poppy is one of the plants of June, and it interests everyone. The stems and large prickly leaves are grayish in color, suggesting the thistle; but the flowers, with delicate white petals, are distinctly poppy-like. The plants have a bright yellow-colored juice which sticks like molasses or tar, as is soon learned by the unwary one who may attempt to carry home a specimen.

FIG. 20. Evening-star. A rather rough or bristly plant with handsome yellow flowers. It belongs to the plains and lower foothills.

Pink cleomes, in abundance, line the railroad tracks in midsummer, and greatly modify the landscape. The cleome is of such interest that reference is made to it in other chapters. Owing to the somewhat heavy perfume, some unpoetical Coloradoans name it "skunk weed" but it is much better called "Colorado bee plant." The Colorado bee plant attracts bees in great numbers and hence is a joy to the insect collector. It is a member of the caper family of plants, very closely allied to the mustards, as its flower structure shows. From the railway train or automobile

it is seen as a tall herb with an abundance of moderate-sized pink or purplish flowers in loose clusters. As the flower fades, the pod-like fruits grow, hanging on long slender stalks below, while the newer flowers in the upper part of the cluster are still in fresh bloom. (Fig. 19.)

Sunflowers are common roadside plants of midsummer and there are many species, but all face the sun in the morning and may even turn with it to some extent during the day. The genus to which sunflowers belong is Helianthus, the Greek for "sunflower." The common sunflower of the highways is really of the same species as the cultivated plants which are raised either for ornament or for the seeds which are used as poultry feed.

Shrubs of Gulches and Slopes

At the sides of small gulches which are passed by the train or automobile, there are various shrubs which show by their stunted form and profuse branching that the soil is dry. (Figs. 21, 22.) Yet the soil is not so dry as that of the level plain, for on the plain, shrubs are not able to grow at all. Most common of the shrubs of these sloping banks, is the three-leaved sumac or skunk bush. Mountain mahogany may also be seen here and there, and in passing from the plains to the foothills and mesas, still other shrubs become frequent. Everywhere south of Denver along the mountain front, the most conspicuous shrubs are the oaks. These are of many species but are all known as "scrub oaks," though some reach the dignity of tree form even if not of tree size.

Plants of the Composite Family

In late summer and autumn, many plants are of sufficient size and abundance to be recognized from a car window. Members of the composite, or thistle family, are conspicuous. This is the time of goldenrods, asters, and blazing-stars, common here as they are elsewhere in the western United States. Unfortunately this is the time also of ragweed and marsh-elder and other unlovely and undesirable plant immigrants. But the hay-fever victim in Colorado may get away from ragweed if he can take a trip to the mountains, for these weeds grow only at the lower altitudes.

Different kinds of senecio, or butterweed, may be seen from our moving vehicle. These plants are composites, a foot or more tall, and they have large clusters of yellow flower-heads. As the flowers fade and the fruits ripen, an abundance of white hairs gives the appearance which, no doubt, suggested the scientific name. This name, Senecio, is derived from the Latin *senex*, an old man. (See Fig. 28.)

A kind of rabbit-brush is another of the interesting plants which may be seen; the plants are striking in appearance because of the long narrow leaves which make them look like diminutive scrubby pine trees. The very numerous small flower-heads are a bright yellow. Although the rabbit-brush belongs to the sun-

Fig. 21. Three-leaved Sumac (at left). A common shrub of dry ridges. It turns coppery red in autumn.

Fig. 22. Mountain-mahogany (at right). A shrub of ridges and slopes, often forming dense scrub.

flower family, it is distinctly shrubby instead of herbaceous. It does not die clear down in autumn, as do goldenrods, asters, and sunflowers, but grows from year to year, developing stems as thick as a man's arm. This development of shrubby growth is uncommon among composites of temperate regions, but in the tropics there are not only shrubby, but even tree-like plants of this family.

The March of the Seasons

Visits to the plains at different times of the year afford views of diverse appearance. Even a few weeks' time works a great change in the aspect of nature. Early in the spring, the sand lilies and other vernal flowers are abundant, before the winter brown of the dry grass has changed color. Later, all is green, following the appearance of spring rain or snow. Soon a great wealth of vegetation appears, the flora consisting of grasses and many profusely-flowering herbs. These latter are able to blossom early in the season, making use of the food which accumulated in the roots during the previous year's growth.

Midsummer's bright days bring a ripening of grasses, and the fruit and seed development of the flowering herbs of springtime. But these are hardly to be noted from a railway train or automobile. There are not many new flowers; indeed, this is a "between-season" period, the plains showing much less of color than during other parts of the growing season. But the different plant associations now become apparent and can be recognized without difficulty: short-grass, wire-grass, bunch-grass, and others. The thread-leaved sage of sandy soil has developed far enough to give its silver-green tone to wide stretches of sandy untilled land, and the roadside sunflowers have drawn lines of gold which flank the highways.

In late summer and autumn, there is a period of minor floral display on the plains and in the foothills, when the shrubby and tall herbaceous composites reach the limit of their growth and conceal, in many places, the fading grass. These plants have long roots and are able to absorb water and maintain a steady growth through the season, instead of dying down in June as do the early-blooming flowers of spring.

The Plains and their Crops

To reach the mountains from Denver there is always a ride of ten to twenty miles on the plains, so that one need be in no hurry to look for mountain plants. These are more fully considered elsewhere in this book, although a few of the more conspicuous are treated toward the end of the present chapter. There is really a great deal of interest without going up to the mountains at all. In looking away to the east we recognize the

vastness of the region, which spreads out like a great sea, meeting the sky afar off at the horizon line. These great plains extend all the way from the eastern base of the Rocky Mountains to the middle of Kansas and Nebraska, far south to Texas and north to the Dakotas and the newly-opened districts of Canada.

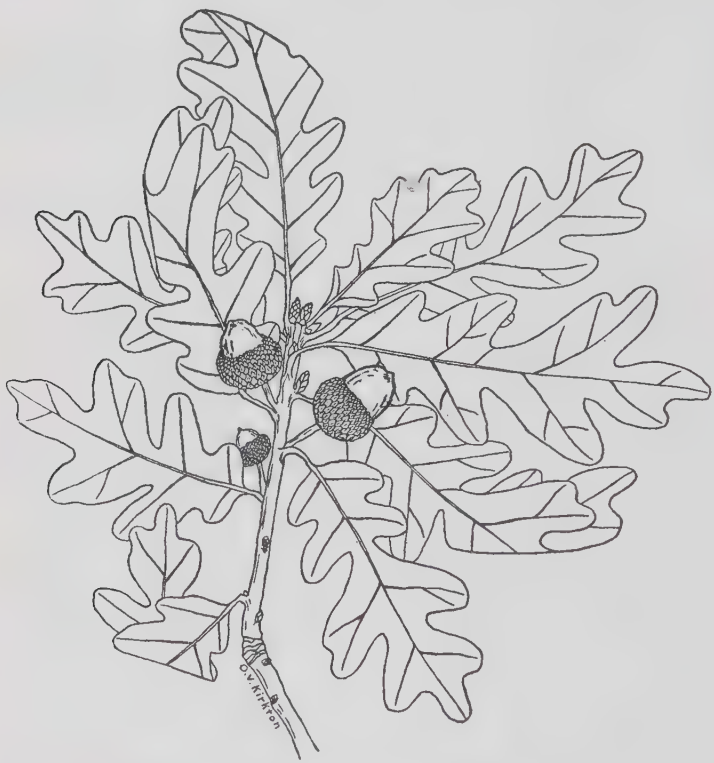


FIG. 23. Shining Oak. This is one of the larger scrub oaks of Colorado. Oaks are very abundant on ridges and slopes in southern and western Colorado.

The plains are no longer thought of as the "Great American Desert", for irrigation is making them "blossom as the rose". With the increase of storage reservoirs, more land is each year brought under irrigation, the flood waters of early spring being stored up and doled out, as needed, to the thirsty land.

Soil such as the Illinois farmer is wont to see in his fertile fields, is not found in Colorado. Indeed the rancher of the Rocky

Mountains does not judge of his soil by its color. There is almost no black loam in the State. Instead, there is the dull brown or red material carried down to the plains by creeks and rivers, and originally produced by disintegration of mountain rocks. Yet this most unpromising looking soil is wonderfully fertile and produces large crops. Farmers of Colorado who have good water rights are always sure of abundant harvests. Dry summers do no harm when there is plenty of water in the ditches from melting snow on the mountains, and the "hot winds" which sometimes kill the standing grain in the unirrigated states to the east have no terror for the Colorado rancher.

While cultivated fields look much the same everywhere, the fields of Colorado are especially luxuriant, for they are supplied with water from irrigation canals whenever they need it and are not dependent on rain, which may fall only at irregular intervals. The person who has not seen a field of dark-green alfalfa set in the midst of parched plains-land, has not realized fully man's mastery over nature. Here, equally as in the building of mountain railways, is made apparent the ingenuity and resourcefulness of man.

Alfalfa is a plant not very different from the common clovers, except for its somewhat bushy form and larger roots. These long roots, extending down into the moist sub-soil, absorb water, even when the surface of the ground is dry and dusty. Hence, an alfalfa field does not need irrigation at frequent intervals, but requires a few thorough soakings each season. Many people imagine that alfalfa has always been grown in the West. Indeed, so far as the history of white people is concerned, this is almost true. The plant is, however, a native of the Old World, where it is much grown. It was brought to California in the early days, by the Spanish fathers, and was found well adapted to the soil and climate. Since then, its cultivation has spread eastward, until now it forms one of the principal farm products from the Pacific to the Great Plains. A field of alfalfa in bloom displays a beautiful harmony of color. The flower-clusters are composed of many dark-purple or bluish blossoms, and with the somber green of the foliage a most restful and pleasing effect is produced.

Of the cultivated crops which may be seen from the car window in a short trip out of Denver, the next in interest is the beet. People who have the idea that sugar is a tropical product

may appreciate the statement that the greater part of the world's supply of sugar now comes from beets raised in the temperate zone. Colorado and Utah have just made a beginning in the sugar industry which has been so successfully carried on in the countries of central Europe. It may be of interest to note that sugar beets are white, not red as are table beets, and that they are long and large, extending a foot or more into the soil. The tops are green, without the reddish tinge which belongs to the leaves of ordinary garden beets.

FIG. 24a. Butterweed (at left). A yellow-flowered composite. There are 66 species of this genus (Senecio) in Colorado.

FIG. 24b. Rabbit Brush (at right). A composite of shrub-like form. Flowers yellow, in late summer. The plant is a species of the genus Chrysothamnus.

In the low river bottoms along the Platte near Denver, a considerable amount of garden produce is raised. Celery does especially well there and, on this account, the pascal celery of Denver is becoming well known in many places outside of Colorado. Tomatoes, peas, and beans are much grown for canning by the large establishments scattered through the cities east of the mountain front.

Wheat, oats, barley, rye, and maize can be raised in the fields of the plains region and may be seen from roads or railways. Oats

grows well in mountain valleys, where it is much planted for hay, the climate being too cool for grain to ripen. Colorado wheat grown under irrigation is a softer grain than that of Kansas and Minnesota, but it makes good flour when mixed with hard wheat. On dry-land farms in Colorado, hard wheat is grown to some extent, especially the very hard macaroni wheat. A few years ago it was supposed that corn could not be grown in Colorado because of the cool nights. Now, however, various improved varieties are successfully cultivated. In some counties the annual "corn show" is an important event. Wheat and corn are usually grown under irrigation, but it is possible to get fair crops on "dry land" when seasons are favorable. Unfortunately, it is impossible to predict wet and dry years; so oftentimes the dry-land farmer has very little return from his fields, and must depend for his living upon his sheep or cattle.

Potato fields are not confined to the plains region but are often found tucked away in secluded gulches of the foothills country even high in altitude, as 8,500 feet. Potatoes grown on the plains are of large size and the yield is high, but potatoes of the mountains are greatly esteemed for texture, flavor, and keeping qualities. Fields of potatoes at high altitudes stay green all summer and come into blossom in August, rather than in July as they do in the plains region.

Small-fruit farms and a few orchards may be seen on almost any journey. Strawberries and raspberries do very well in the vicinity of Denver, and also such fruits as apples and plums. Cherry orchards are planted in limited localities of the northern part of the State. The climate there is not mild enough for successful peach growing, although some seasons permit the development of a good yield from the few trees that are planted. Colorado peaches, so well known far and wide, come from the Grand River valley on the Western Slope. A trip through that district is especially inviting at peach-blossom time.

Tree Planting and Seed Growing

So far as is known, the first planting of fruit trees within the territory which now forms the State of Colorado, was in the year 1863 at or near Golden City. Cottonwoods were taken from the river bottoms of the Platte and transplanted to two homesteads near Boulder in the spring of 1864, and to Denver in 1865. At

FIG. 25. The Blue Columbine, State Flower of Colorado. This is a plant of the true mountain country. The Columbine may be grown in gardens. Wild plants should not be picked for decorations.

present the commonest shade trees are the maples, elms, oaks, locusts, poplars and cottonwoods, and the Russian olive. Then there are the spruces, pines, and other evergreens,—perhaps 150 kinds of shade and ornamental trees in all.

Trees and shrubs for planting, are now being raised by local nurseries, and Colorado nursery stock is competing favorably with that from other sources. The growing interest in landscape gardening has created a demand for plant materials of decorative value.

The cultivation of native plants will, in time, afford much botanical information. On growing these plants in the garden, they may be fully studied as to their real nature. It has already been noted that when certain different kinds of Colorado oaks are planted side by side, two or more supposed species turn out to be the same, although when growing wild on different soils they appear very unlike.

Seed-growing could be made an industry of some importance in the State. Growers are already producing some seeds for home use and for shipment. The varied geography and climates of Colorado should afford ideal conditions for seed production, since some seeds are produced more satisfactorily in a warm, others in a cool climate.

Trees of the Foothills

In traveling beyond the plains into the foothills and above, the vegetation most likely to attract attention will be that formed by trees. It is possible to recognize most of the different kinds from a moving train or even from a speeding automobile. At lower levels, especially in the southern and western parts of the State, the cedars (or junipers) and the pinyon pines reach down to the limit of the plains.

Cedars are of narrow conical or cylindric form and often most beautifully symmetrical. The finer twigs of the closely-placed branches are clothed with overlapping scale-like leaves which are of a bluish-green or whitish-green color. Cedars may remind one somewhat of the European cypress or of the American arbor vitae. On exposed and windy ridges or rock cliffs the cedar is greatly distorted and would hardly be recognized save by its small leaves.

Pinyon pines are not seen in the foothills near to Denver, although a few are known in northern Colorado. Near Colorado Springs, however, and to the south and west, this large-seeded pine, which supplies the "pinyon nuts" of fruit-stands, is quite abundant. The needles are short, hardly pine-like at all because

of their shortness, and the trees are much more compact than most pines; but even from a car window they may be recognized as pines rather than spruces, firs, or cedars. The pinyon never grows in the higher mountains. So its location, as well as its appearance, can be used to identify it.

The most abundant trees of the lower foothills are the rock pines. They have the usual open branched form and long needles of typical pines, and it is scarcely possible for any one to mistake them for trees of any genus other than Pinus. The bark is thick and dark red-brown. On old trees it is deeply furrowed. Higher in the mountains other kinds of pines occur: the lodgepole, foxtail, and limber pines of cooler and often more wind-swept localities.

The Douglas spruce, or Douglas fir, has a rather open and feathery appearance. It is not always easy for one, even though he be acquainted with the trees at close range, to distinguish, at a distance, the Douglas spruce from one of the true spruces. Yet in general aspect the trees are different. Engelmann spruce, Colorado blue spruce, and the balsam and white firs belong to the true mountain districts and to the upper foothills. All are straight, compact trees having short needles. Cottonwoods and willows along streams, as well as aspens on steep slopes and in seepage areas, can all be seen even by the traveler who goes with much speed; and there is a satisfaction and a pleasure is seeing and recognizing them.

LICHENS

No one can be out of doors in Colorado without becoming acquainted with the lichens (pronounced "ly-kins"), those grayish, reddish, or greenish growths, so common on rocks. The non-botanist is likely to think of them as mosses, but they are more nearly related to molds and mushrooms. Some lichens grow on trees, as crusts upon the bark surface or as hanging festoons, but most of the Colorado lichens are upon rocks. These rock lichens are a source of perennial joy to all who ramble among the hills. Every rock has its patches of olive, pale green, yellow, red, or brown. Sometimes a huge boulder is completely covered with lichens of one color, or it may be mottled with irregular markings of various colors. Great areas of some one shade or tint, many feet across, delight the eye. A trip through a narrow canyon reveals marvelous color effects at every turn of the road.

Abundant Wild Flowers; Need of Conservation

Many flowering plants of the foothills and mountains exist in such numbers that when in blossom they color whole hillsides, or give brightness to broad openings in the forest through which automobile roads may wander. Most of these flowers will be considered later, and need only be mentioned at this point. Such are the pasque flower of early spring, the sunflower-like arnicas which grow in meadow land, the golden pea, blue larkspurs, blue beard-tongues, red and yellow Indian paint-brushes, pink or red gilias, and the mariposa lily. Columbines were formerly seen along roads through the forest but these plants are now nearing extinction in the frequented districts. Unless attention shall be given to saving them, they are destined to become but a memory.

Plant Ecology of Mountain Travel

Even when journeying rapidly through the mountains, it is possible to learn some plant ecology. Striking differences are seen in the vegetation of north and south canyon walls. The north-facing slope may be clothed with a dense stand of trees, while the slopes exposed to the sun may have a sparse tree growth, with wide grass-covered stretches. In some canyons, there is not only this difference in the number of trees on the two slopes but the particular species may be different: spruces in the shade, and pines in the sun. Shrubs, as well as trees, are easily recognized as belonging to certain exposures or to certain soils. The wild red currants and thimbleberries grow in the sun, but mountain-ash and elder belong to shady situations except at high altitudes where, even in sunny places it is cool enough and moist enough for them.

In crossing a mountain stream, the flash of brook-bank flowers is seen; they belong to plants of black alluvial soil, so rare in mountain districts. An arid hillside is bright with gay-colored flowers of dry-soil plants, or xerophytes; a melting snowbank is fringed with moisture-needing buttercups and mountain daisies.

At the highest altitudes, where railway trains puff prodigiously, and even high-powered motor cars have trouble with the steep grades, there is still much of botany to be seen. Timberline trees of grotesque form occur in scattered groups, or in long sloping windrows; bright patches of color in open spaces reveal the presence of mountain pink, or forget-me-not, or gold-flower;

growths of dwarf willow skirt the shores of a charming lake, followed higher up on the banks by a fringe of Indian paint-brush and other plants of mountain meadows.

Thus it is, that even the traveler-in-haste can see a little of plants and of plant life. If time can be taken for rambles in the woods, cross-country walks through open meadows and across plain, or long climbs over foothills and up mountain-sides, the traveler will see far more than from a moving conveyance. But what he sees will depend very much upon himself. Nature reveals most to the fortunate person who is both poet and devotee of science; but to either poet or naturalist she can relate very much of beauty and of interest. Yet for even the most prosaic person, and for the one who has had no training in the exact discipline of the laboratory, she has also a story,—more simple, less detailed, but full of charm and meaning.

Chapter 4

COLOR IN PLANTS

The green color of plants is due to a substance known as chlorophyll—literally, "leaf green". This material gives color to certain small granules of living matter, or protoplasm, in leaves and young stems, forming what are called chlorophyll bodies, or chloroplastids. Great numbers of these may be present in a single cell of a leaf. Usually they are lacking in the epidermis, or skin, but are numerous in the parts just beneath.

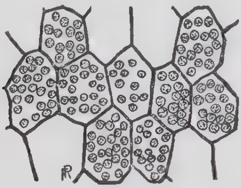
As is well known, if a leaf is placed in water the color does not come out. To put this fact as a scientific statement, it may be said that chlorophyll is not soluble in water. It is not in solution in the cell-sap, which is chiefly water, but is confined, as previously noted, to certain definite parts of the living substance, and gives color to these. The chlorophyll bodies can not be seen with the naked eye because of their smallness, but are easily recognized with a compound microscope. In order to see them, it is necessary to examine a very thin slice of some common leaf or stem, or else to look at them in a moss leaf. A moss leaf is so thin that it can be placed in a drop of water on a glass slide and examined directly; it is not necessary to cut a section. The chloroplastids are seen as round, foot-ball shaped, or door-knob shaped bodies, 20 or perhaps 50 in a single cell of the leaf. (Fig. 26.)

Photosynthesis, the Work of Chlorophyll

The true physiological role of chlorophyll is food-making. Water and carbon dioxide are the raw materials of the process. The water is absorbed from the soil by the roots, and passes up through the stem into the leaves. Carbon dioxide diffuses into the leaf from the surrounding air. These two substances are made to combine, within the leaf, forming a kind of sugar. Since this combination takes place only in the presence of light, the process is called photosynthesis. It is a process belonging only to plants with chlorophyll. Variegated leaves, with white stripes or margins, produce food only in their green portions.

It may be objected that some plants are red, not green at all, hence chlorophyll can not be necessary. The fact is, however, that plants with red leaves, as beet, coleus, and canna, really have

a basis of green. If they be put into boiling water, the red color is removed and the green is now apparent; the chlorophyll was present all the while but was masked by the red sap. Red seaweeds too, those graceful growths in deep water along the coasts, become quite green in time if placed in fresh water, which draws out the red coloring matter. They have the green color, but this is not seen because of the red substance also present. It may be of interest to note that if seedlings are grown experimentally in a soil absolutely lacking in iron, they do not develop chlorophyll; hence they die as soon as the food material in the seed has all been used.



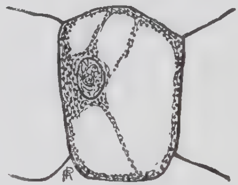


FIG. 26. Portion of Moss Leaf (at left). A piece of leaf magnified under the compound microscope. Each of the cells has many green plastids.

FIG. 27. A Cell of the Flesh of Tomato (at right). From a preparation seen with the compound microscope. The small dots represent the red plastids which give color to the inside of a ripe tomato. In the unripe fruit the plastids are green.

Some plants have no chlorophyll, as mold, mildews, mushrooms, puffballs, Indian pipe, and certain non-green orchids. But these can not make their own food. They steal it from some living plant or else use the material of some dead plant or animal body, or the products of a living one. The mistletoe of Christmas time makes a part of its food but takes the rest from its host, the oak tree. Our pine mistletoe of Colorado has no chlorophyll, hence obtains all of its food by robbery.

In the final analysis, it is found that (except for a few bacteria) every plant and animal gets its nourishment by means of chlorophyll. Even human beings are dependent on chlorophyll. Much of their food is derived at first hand from plants, as flour, meal, vegetables, and fruit. Meat we speak of as animal food, but the animals which furnish beef and mutton get their food from plants. Chlorophyll is thus seen to be the basis of all life on the earth. But it is really only a converter or transformer of the energy of the sun. The sun itself furnishes the energy for plants, animals,

and men. The sun thus gives meat and raiment as well as warmth and light.

THEORIES AS TO COLOR IN NATURE

Chlorophyll absorbs certain of the sun's rays, reflecting back to our eyes the rays of green. It is not known that the greenness is of any special importance. It is probably a mere incident. So of colors generally in nature. For the most part, they have no significance, although from their constant presence, people may be led to think them highly important.

Much has been written about color in nature. Once it was thought that the glory of a red sunset was a display of the flares of hell. Few would now give that explanation. It is stated that color in flowers is developed to attract insects for carrying pollen. The markings on butterflies are "protective", "warning", or "attractive". The white tail of the deer is stated by one writer to be of great help to the young in following the doe, while she is running from a pursuer. But this writer fails to note that this same white tail forms an excellent mark for the pursuing beast of prey or for the hunter. Every patch of color on a flower is supposed by some "naturalists" to have a special meaning. Either it is a guide to the insect, showing the way to the nectar, or it is a blind to keep the insect away from the pollen which it might eat.

Many colors in plants probably have no significance at all as colors. Who would be so rash as to say that the red of pigweed root or the yellow of the carrot have any value to the plants which produce them? And what about the color of woods? Do the black of ebony or white of the wood of holly make the trees more able to resist attacks of insects? If the colors of pigweed and carrot, of ebony and holly, have been developed without reference to insects or other creatures, what shall be said of colors in the rose and the violet?

Among animals, some very interesting and brilliant colors appear in internal organs. Lungs are a beautiful shell-pink, the heart a mahogany brown, the liver a still darker brown; bile is green in some animals, light brown or yellow in others; fat is cream-colored or white, bone marrow is dull red. If all of these colors can occur inside of an animal without value in protecting from enemies or without importance in aiding the young, why not outside colors as well?

NON-GREEN COLORS OF PLANTS

With this passing comment on the prevailing fashion of "explaining" so much in natural history it will be worth while going on to a description of colors other than green in plants. These are seen chiefly in flowers and fruits but are found also in buds, leaves, stems, and roots. We need but recall the red buds of the maple, the purple leaves of barberry, yellow twigs of mountain-ash, and red root of beet.

Foliage leaves seldom show other colors than those formed by combinations of red, yellow, and green. Even the steel-blue

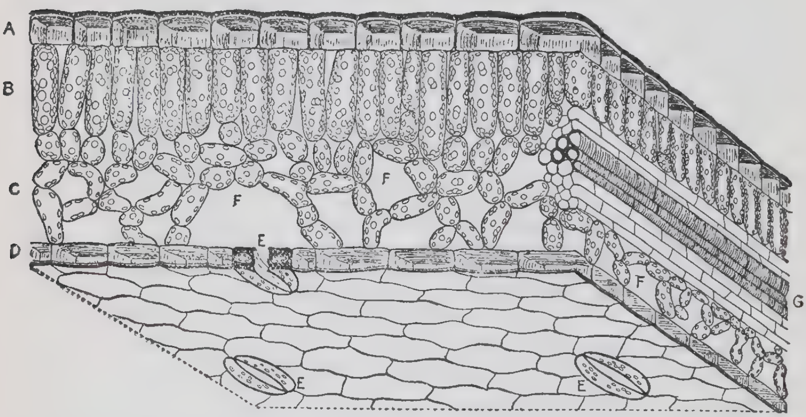


FIG. 28. Drawing of Leaf, as seen with microscope. *A*. Upper epidermis; *B*. Palisade; *C*. Spongy tissue; *D*. Lower epidermis; *E*. Air pores or stomata; *F*. Air cavity; *G*. Portion of a leaf vein cut lengthwise. (From Sinnott's Botany.)

color sometimes seen in the autumn leaves of ash is but a combination of dark green chlorophyll and a small amount of red in the sap.

In flowers, however, there are many more colors. The blue of the harebell is due to a blue coloring substance in the sap which, curiously enough, is the same substance, anthocyan, that gives the red tone to the maple leaf. The difference depends on the presence of acid in the sap of the maple. Anthocyan, is commonly a blue subatance but in an acid solution it becomes red. If a blue flower is held over an open bottle of hydrochloric acid it turns red and if a red flower or leaf is treated with ammonia water it becomes blue—or greenish, if certain other substances exist in the flower.

Since in the chemical processes of decay set up in autumn, acids are always developed, it happens that autumn leaves are often red in color but never blue.

The production of anthocyan in leaves frequently is confined to the stalks and the veins. This is strikingly the case in many maple leaves. Not all the leaves on a tree behave in the same manner. Indeed there is considerable individuality among leaves both in the development of anthocyan and in the changes in chlorophyll which bring about the yellow colors. Such differences depend on the vigor of the individual leaf, the amount of water with which it is furnished, the light it receives, and the closeness to other leaves on the same branch.

Before leaf-fall in autumn, the chlorophyll bodies undergo certain chemical changes, resulting in shades of yellow or brown. In maples and aspens these changes are slow, and the yellow color continues for a long time. White oaks, elms, and hackberries, on the contrary, usually change quickly and the leaves soon become a dull and uninteresting brown. In the maple, as already noted, a red coloring matter often develops in the sap and if in sufficient amount it gives color to the entire leaf. At other times it merely modifies the yellow to an orange.

Colors of certain fruits such as lemon, orange and tomato are due to the presence of "color bodies", or chromoplastids, in certain of the cells below the epidermis. These color bodies are merely small portions of the living substance which have in them a fatty yellow or reddish pigment. As a rule the more opaque reds of fruits are due to such color bodies. Transparent colors, as seen in plums, the reds of apples, or the purple flowers of petunia, are caused by anthocyan. Likewise the red in the skin of a tomato is due to anthocyan color but the redness of the internal flesh is caused by chromoplastids.

There is no white pigment giving the color to white flowers. A Mexican poppy, for example, gets the whiteness of its petals from the air between the cells which form the petal. This air reflects the light and gives the appearance which we call white.

Some flowers show their color chiefly in bracts below the flower cluster. The Indian paint-brush is a good example. In this plant the flowers themselves are so much enclosed in bracts that they are hardly seen and it is these colored leaves, yellow,

red, orange, or crimson which attract the eye and make the plants so conspicuous.

Snow-on-the-mountain is a plant also conspicuous for its bracts. These are green, edged with white, and give a striking appearance to the plant. The individual flowers are small, so that were it not for the white-margined bracts the plant would attract little attention. Our snow-on-the-mountain has a well-known cultivated relative, the poinsettia, in which also the color occurs in the bracts.

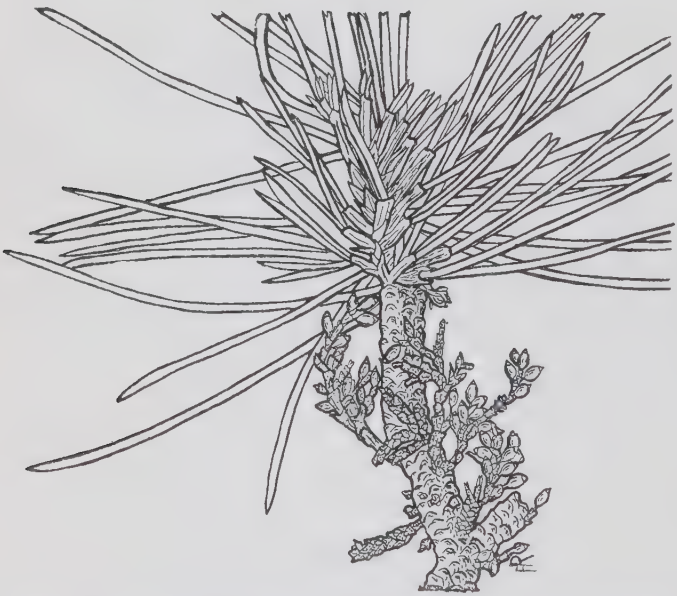


FIG. 29. Pine Mistletoe. A parasite often on pine trees in the Rocky Mountain region It produces great numbers of white, berry-like seeds. The plant is without chlorophyll and is of a yellowish color. Pine trees infested with this mistletoe often are deformed and produce clustered bunches of twigs known as "witch's brooms".

White varieties of colored flowers are not uncommon. The botanist Asa Gray said that every flower was likely to show a white variety. Such varieties are more likely to occur in blue or pink flowers than in others. Yellow does not so often give way to white. Beard-tongues, columbines, harebells, and phloxes offer examples of flowers with a frequent tendency toward white; really an absence of color.

Color variations of different sorts are found from time to time in the wild state. Blue lupines may at times be pink, red loco weeds show an occasional plant with greenish-blue flowers, and the common yarrow, ordinarily a dingy white, is now and then pink or crimson. All of these variations indicate that flower-colors are not absolutely fixed and stable things but may vary in different directions.

Attempts have often been made to connect flower coloring with season of blossoming or with different soil, moisture, or climatic conditions, but all such attempts have failed. There are pink, blue, yellow, and white flowers in spring, summer, and autumn. All these same colors are seen in plants of hillside, of meadow, and plain. It must be then that colors of flowers are of slight importance or else the basis of their importance has not yet been discovered.

Flower-color and Insect Visits

In regard to the showiness of flowers as an element in attracting insects for pollen-carrying, so much has been written that it seems unnecessary to say more. But the fact is that what has been written for popular reading has all been on one side. It is generally stated that flowers of conspicuous color require the visits of insects in order that pollen may be carried to the stigma of the pistil and the production of seed be made possible. And it is stated that the bright colors serve to attract the insects which would otherwise be unable to find the flowers. Now these statements are hardly in accord with ascertained facts. It is true that many flowers must be pollinated by insects, but that the color of the flower is of consequence is not proved. Some interesting experiments made by students of the subject show that when the colored petals of flowers are removed from the bud that the seeds ripen just as usual and that insect visitors are as frequent to these mutilated flowers as to the ordinary ones. If this shall be proved in all cases it will mean that insects are attracted by scent or in some other way. It has always seemed to the writer highly improbable that insects could make much use of flower color in identifying the kinds which they would want to visit. The eyes of insects are very simple structures and they may be of no great value in determining color.

Flowers there are in considerable number which are visited by insects and yet are inconspicuous. The catkins of willows sometimes have great swarms of bees around them in early spring and the ill-scented flowers of wild smilax never lack abundance of flies.

Differences in Flower Color of the Same Plant

As a rule all of the flowers of the same plant are alike in color, but this is not always so. Light and dark blue or deep and pale crimson blossoms may be seen side by side. In the case of composite flowers such as sunflower, Easter daisy, and asters the

Fig. 30. Indian Paint-brush (at left). The conspicuous part (red, yellow, pink, or crimson, according to the species) is made up of colored leaves which surround the flower.

Fig. 31. Snow-on-the-Mountain (at right). This plant, like the poinsettia of the florists, has small flowers but is conspicuous because of the leaves which surround the flowers. These upper leaves in snow-on-the-mountain are conspicuously white-margined.

two sets of flowers which make up the flower-head are generally quite unlike. An ordinary "sunflower" consists of a mass of small brownish flowers in the center and a single row of yellow ray flowers around the outside. In asters the central (disk) flowers are yellow and the ray flowers purple or white. Gum-weed, however, has both disk flowers and ray flowers yellow.

Fruit Colors

The colors of fruits are many and varied. With them it seems likely that the color may at times be of importance in attracting

birds. When a bird eats a cherry or a raspberry, the seeds pass through the digestive tract uninjured and may be deposited many miles away. This is of great value to the species as the offspring then do not all grow up around the parent to choke it and themselves by their crowding. Birds are very keen of vision and can probably see bright-colored fruits a long way off. In fact their eyes are quite as good as the human eye for near-at-hand objects and much more keen in distant vision. Plants which produce berries that are white, or colored to contrast with the general green of the foliage, may be scattered rapidly by birds. In this way then the color may be of advantage. It must not be forgotten, however, that many fruits have bright colors inside which would not serve in this manner at all. The watermelon with its red flesh is certainly not adapted to distribution by birds or other animals because of its color.

It is always well to be on guard against misinterpreting the facts of nature or reading into them things which are not there. There is no reason to suppose that colors have been developed in fruits in response to a need for seed distribution. It is best to think that certain species have a natural tendency to produce colored sap in their fruits while other species have a colorless, transparent sap. These characters generally extend through whole plant families. Of course, if the plant with colored sap has a better chance for distribution than the one with uncolored sap it may survive in times of adversity when all of the plants of the other type are killed out. So the color will be perpetuated. But in any case it must not be supposed that the color was developed in order to insure proper seed dispersal.

AUTUMN LEAVES

Autumn colors have long attracted the attention of botanists and still more the attention of poets. Even the unpoetical, and those without scientific knowledge are interested in the subject. Some have thought the colors produced just to delight the eye of man; others have considered them from a scientific or a pseudo-scientific aspect. Indeed, there has been much arm-chair speculation as to their significance. Of the many theories of autumn color undoubtedly the prevailing idea is that frosts acting on the leaves induce the color changes. This theory is false. Many

leaves show autumn colors long before the first frost. Poison ivy and Virginia creeper begin to turn in August, and individual maple trees may show red and yellow as early as July. In Java the leaves of the terminalia trees exhibit handsome "autumn colors" before they fall off in March, although the temperature may not have been as low as 60 degrees Fahrenheit.

Some botanists have held that, although the red colors are not developed in response to frost, yet the lower temperature of late summer and early autumn aid in the development of color. This may be the case to some extent but the real explanation seems to be that the leaves are ripened at the close of the season no matter what the temperature. In fact the most gorgeous display of color is generally noted in seasons when frost is greatly delayed.

If two thermometers be placed in the sun, one with a red leaf around its bulb and another with a green leaf, the former will soon show a somewhat higher temperature, even five or ten degrees. It has been suggested that the red color of autumn leaves is a "warming up" device to help the leaves in the cooler weather of autumn. Such warming up occurs, however, only in sunshine. At night when the plant is most in need of something to protect it from cold the red coloring matter is of no advantage. Hence it seems reasonable to assume that the warming up is merely incidental and that red colors, if they have any real significance in plant economy, need further investigation.

Probably the theory of the value of red coloration which is now most held by botanists is the so-called "screen theory". This is based upon the well-known fact that the living substance of a leaf is easily injured by too intense light. During the summer when the leaf is in full vigor the bright light does no damage, or at least any damage done may be quickly repaired. In spring and autumn the plant is not so active and its powers of recuperation are impaired. The red coloring of the sap in young shoots of maple or in autumn-leaves may diminish danger of injury to the tender living substance just as the ruby glass of the photographer's dark-room window saves the sensitive plate from destruction.

It is easy to see that, whatever the value of the red color, this color is called forth either by immature conditions or by de-

clining activities. In autumn when the air is cool and the living substance has passed its prime the leaves redden. Young shoots in the spring, likewise, may be quite red before the living substance has attained full vigor. Maple trees on overflowed land sometimes become red as early as June or July and the same result may follow in midsummer if a tree be deprived of its customary supply of soil moisture.

It is possible that the red color of autumn leaves has no significance at all in the plant's economy. Elms and cottonwoods do not turn red and yet they thrive in the same region with maples. The red may be merely a death color and have no more meaning than the death changes of animals have to animals. No one would claim that the yellow and brown leaf colors are of use to the plant, and perhaps the red color also is not. But at any rate the red and yellow and orange are beautiful to look upon and anyone interested in plants at all enjoys a landscape made brilliant with their presence.

SOME COMMON WILD FLOWERS LISTED ACCORDING TO COLOR

It may be of interest to the motorist or railway traveler and still more to the one who strolls, walks, or climbs to know some of the plants which give color to the landscape. Although there are many flowers of great beauty, large size, or striking color in the Colorado fields, meadows, and woods most are just scattered here and there. They are charming in themselves when seen near at hand, but they are not found in great abundance. If conspicuous masses are seen they are likely to be made up of some of the flowers listed below under different colors. The list is necessarily incomplete, because almost any conspicuously-flowered plant may be locally abundant. No great number of kinds will be found abundant on the same date.

YELLOW

The *Golden Pea* occurs in meadows of the plains region in the spring, on hillsides of foothill and montane districts in summer. The color may often be seen a mile or more away in open forest land. (Pea Family.)

Arnica, of many species, occurs in moist meadows and swamps. It may be so dense as to shut out nearly all view of other plants. Our native Arnicas are not the ones from which the pharmacist prepares his tincture, but they would probably serve quite as well as the old-world species. (Thistle Family.)

Golden Aster, or *Chrysopsis*, is usually the most abundant yellow flower in mountain grasslands during August. (Thistle Family.)

Dandelion, just the common old-fashioned weed found everywhere, turns Colorado lawns to gold in May and June. (Chicory Family.)

Sunflowers are as yellow and as abundant along highways in Colorado as they are in Kansas. They occur in the plains region, never in the cold parts of mountain country. If what appear to be sunflowers are seen at high altitudes the plants are probably cone-flowers (Rudbeckia, Ratibida) or false sunflowers (Helianthella, Heliopsis). (Thistle Family.)

Yellow Paint-brushes grow in pine forests, mountain meadows, and even above timberline. (Figwort Family.)

The *Butterweed*, (or *Senecio*) of numerous species, is known from plains to timberline, and above; some of the species grow abundantly in cut-over or burned timberland. (Thistle Family.)

The *Sulphur Flower*, known for its sulphur color and abundance of small flowers in beautifully symmetrical umbels is one of the best-known Colorado wild flowers. Some of the species are not yellow, but straw colored. All tend to become pinkish when they fade. (Smartweed Family.)

The *Brown-eyed Susan*, known and loved by children of all ages, sometimes makes up a large part of the vegetation in wet meadows of 7,000 to 9,000 feet altitude. (Thistle Family.)

Cinquefoils of numerous species and genera (Potentilla, Sieversia, Dasiphora, Drymocallis, Argentina) are found at all altitudes, in both dry and moist situations, but especially are they common in meadows of the foothill and montane zones. (Rose Family.)

Gum-weed, Grindelia, is known for its sticky stems and flower-heads but it furnishes to dry roadsides and sunny open stretches one of the purest yellows seen anywhere in nature. Since gum-weed blooms late in the season it is conspicuous at a time when very few other flowers are to be seen. (Thistle Family.)

WHITE

Yarrow, almost the same as that of Europe which gives the Shakespearean oath "by yarrow," occurs chiefly in meadow land and moist forest. Along roadsides it often produces ribbons of white parallel for many rods on both sides of the highway. Yarrow is one of the few species of plants found at practically all altitudes. It can exist in all the different climates which Colorado affords. (Thistle Family.)

White Loco belongs to the plains and foothills. It is most beautifully white; there is no suggestion of a soiled condition demanding the laundry which one thinks of in viewing the yarrow. (Pea Family.)

Swamp Hollyhock, or *Sidalcea*, may form handsome masses in wet grounds along streams, at altitudes of 7,000 to 9,000 feet. The plant has smoother and finer foliage and also smaller flowers than the hollyhock of our gardens. (Mallow Family.)

The *Sand Lily*, so abundant in dry grassland of plains and foothills is one of the flowers which delights all who walk the fields in spring. (Lily Family.)

White Evening-primroses as large as the largest of roses, often fill up completely an abandoned field. These plants, although they are "evening" primroses do not open in the evening but behave as most flowers do, being full-blown at day-break. (Evening-primrose Family.)

Prickly Poppy, or *Mexican Poppy*, a coarse, spiny plant about two feet tall, has flowers larger than the largest wild rose. Great masses of these poppies may be seen at the lower altitudes. (Poppy Family.)

Red, Pink, Crimson

Red Paint-brushes of various shades and hues, scarlet, vermilion, and even old rose, are plants of wet meadows and forest openings at nearly all altitudes. (Figwort Family.)

The *Colorado Loco-weed* is one of the best-known flowers of dry grasslands. Certain of the loco-weeds have a bad reputation for injuring livestock, but it is doubtful if they deserve it. There are many species of loco-weeds, but the most widely distributed is the red-flowered one (Aragallus lambertii). It is common in mountain parks. (Pea Family.)

Fire-weed occurs from foothills to timberline, especially in burned-over areas. The seeds have cottony hairs which keep them up when blown by the wind. They are thus easily carried great distances and the plants start readily in any moderately moist soil. (Evening-primrose Family.)

Little-Red-Elephant is easily recognized when seen at close range. The flowers of the closely-packed cluster very much resemble the head and trunk of an elephant. These plants belong to cold marshes and moors. (Figwort Family.)

The *Mountain Pink* has a cushion form often as large as the two hands and covered over with small pink flowers. It is one of the spring-blooming plants of timberline and above where it grows with the mountain forget-me-not. (Pink Family.)

Colorado Bee Plant grows best in sandy soil but occurs in other soils also along highways of plains and foothills. It is a large and tall herb of midsummer with many small pink flowers and pod-like fruits on long stalks. (Caper Family.)

Blue, Purple, Lilac

Bergamot or *Horse Mint* has small lavender flowers in great clusters of heads, each as large as a baby's fist. It grows in the lower foothills in moist meadowland. (Mint Family.)

Beard-tongues, or *Pentstemons*, of which there are 37 species in Colorado, are usually blue but a few are pale purple, some are cream color, and others scarlet. The blue-flowered kinds are the most numerous, occuring in forest openings, on hillsides, and in meadows at all altitudes. (Figwort Family.)

Chiming Bells, Blue Bells, or *Lungwort* with an abundance of long bell-shaped flowers of azure and with bluish-green leaves are well known. Certain of the species in dry grassland are hardly a foot tall; others grow waist high on the margins of brooks. (Borage Family.)

Harebells, known to everyone, grow on canyon walls of the foothills and in open situations at all higher altitudes. (Campanula Family.)

The *Columbine*, State flower of Colorado, formerly abundant almost everywhere throughout the mountains, may still be found in masses just below timberline in less frequented districts. Besides the blue columbine there is a yellow-flowered species in the southern part of the State and a red-and-yellow one on the Western Slope. (Crowfoot Family.)

Pasque Flowers, with woolly covering of hairs on flower-stalk and bracts, and the large, pale blue flowers close to the ground are the favorite blossom of children, because they are the earliest to appear in Spring. They are known locally as "anemones" and occur in foothill and montane situations, particularly on open hillsides. (Crowfoot Family.)

Mountain Daisies, or *Erigerons*, grow at all altitudes, over 50 species being found in the State. The numerous narrow ray-flowers are of all shades of blue, lilac, and purple, some even white, while the center of the flower-head is yellow. (Thistle Family.)

Asters are of many kinds. They are much like mountain daisies, but with ray-flowers broader and not so many to the head, generally fewer than fifty. The asters bloom in late summer and autumn. (Thistle Family.)

The *Forget-me-not* of the alpine slopes is the bluest of blue in color. The plant is of cushion shape often as broad as a man's hand and covered with small flowers which fit together so closely that the fine moss-like foliage is hardly seen. (Borage Family.)

Lupines are sometimes abundant in the foothills, especially the tall, much-branched forms. But tourists who have visited California will miss the great numbers of annual lupines which are so common on sandy soil of the Pacific Coast States. The lupines are easily recognized by their palmately-divided leaves with five or more long leaflets, and the pea type of flower. (Pea Family.)

Chapter 5

PLANTS OF STREAMSIDES AND DITCHBANKS

It is among the plants of streamside and ditchbank in Colorado that the naturalist from the eastern United States will find old acquaintances. The vegetation of dry soil has its own types of plants but streambanks have plants which resemble greatly those of like situations in Minnesota, or New York, or Maine. True enough, these plants which seem so similar are not exactly the same as their eastern relatives but they are so much like them that they occupy the same place in the plan of nature.

Many of the smaller distinctive streamside plants are rather rare. It is possible to spend many years in Colorado without seeing a meadow rue, or baneberry, or cat brier, or true anemone, or a wild sarsaparilla plant,—all so well known in the deciduous forests farther east. Yet along creekbanks where there is good soil, these very plants may be sought and found. It is not often that they are abundant, for there is seldom just the right combination of soil and shade and moisture. Even where these local conditions are favorable, there is still the dryness of the atmosphere to be met. If they are to live at all, these plants must dwell in the shade. Hidden away they are, under the narrowleaf cottonwoods and the willows,—a plant here, a plant there,—and all about them the vegetation of drier and sunnier places.

In the plains region of Colorado, natural tree growth is confined to the banks of streams or the slopes of river bluffs. The usual shade trees of the Eastern States if planted in Denver will grow there, but unless cared for they will eventually die. In many towns of Colorado, and in country districts too, trees have been planted, then cultivated or watered for only a few years, and finally left to themselves. Such trees do not survive. They eventually succumb for want of water. Colorado soil is productive but it must have water.

A traveler, crossing the plains by train, may, from the car window, locate streams by observing the fringing rows of cottonwood trees. These native trees, although accustomed to the dry climate, grow only along water courses. If planted by the rancher

for shade around his house they must be irrigated, else they will die, just as do trees from the Eastern States.

COTTONWOODS

Of all our deciduous trees, the cottonwoods are best known on account of their large size, and because they are frequently planted as shade trees. When the early settlers wanted protection

FIG. 32. Seedling and Seed of Broad-leaf Cottonwood (at left). The small rounded structures are the cotyledons. The next leaves of the seedling are narrow. Leaves produced later are broad and heart-shaped. The seed bears a great many cottony hairs.

FIG. 33. Shiny-leaved Thornapple (at right). A plant of canyon mouths and moist hillsides. The flowers are white and sweet-scented. The ripe fruit is dark red and of berry-like appearance.

from the blazing sun, they went down to the creek, dug up a tree, and planted it before the door. To carry maples or elms across the plains in the early days would have been no easy matter. Besides, it was supposed that only native trees would grow in this country of high winds and bright sunshine. Often the person who dug up the tree for planting did not know the different kinds of cottonwoods apart, and might, perhaps, get specimens

of two or more species, which would then be planted in a row. So it happens that many an old residence may have about it the broadleaf, the narrowleaf, and the lanceleaf cottonwoods. These form a series rather closely alike, and yet different enough so that they may be distinguished. One who wishes to begin the study of trees may well start with these three species, specimens of which are to be found in most of the cities and towns of Colorado located at moderate altitudes.

The cottonwood has a bad name because of the cottony hairs on the seeds, but not all cottonwood trees bear the cotton, which is sometimes so objectionable. The flowers of certain trees produce pollen grains, and those of other trees bear the seed-rudiments, or ovules. In botanical language: some trees are staminate, some are pistillate. The pistillate trees alone produce the cotton, because only these bear the seeds, with their cottony appendages. The cotton serves a useful purpose in the life history of the trees; it makes the seeds buoyant so that they are blown for long distances by the wind. In this way the species is distributed far and wide. But human beings do not like the cotton on their porches and screen doors, nor in their nostrils. If the cotton is really a serious nuisance in any locality, the "cotton bearers" may be cut down, and the staminate trees alone left. These will, of course, not spread cotton. The same relief from cotton could be obtained by destroying all of the staminate trees, for without pollen no seeds would ripen, and there would then be no cottony seed hairs. For new plantings, it is possible to buy from nurserymen the staminate trees only. These are propagated by cuttings. The Carolina poplar and the Andrews poplar, now on the market, are strictly staminate.

There seems to be no difference between pistillate and staminate trees, except in their flowers; but it is possible that a painstaking study would show distinctions which are not at once apparent. The two kinds of flowers are, however, very unlike. Both grow in catkins, but the catkins are of different color. Those having pistillate flowers are green, the others are a brownish-red. They first appear in March or April, varying somewhat in their dates from year to year, according to the weather of each particular winter or spring.

The pollen grains borne by the red catkins are produced in very great numbers. If catkins are blown down by the wind, and fall upon a board or stone, their pollen will be seen as a quantity of bright yellow powder,—thousands or millions of pollen grains. This prodigality of pollen formation is necessary because so many of the grains are lost. Only those which fall on a pistil-tip are of value to the species. Any which stick to twigs, or drop on the ground might as well never have been formed.

The role of pollen is to produce pollen tubes. Each grain which falls on the pistil-tip may sprout; from it there grows out a delicate tube which extends down through the substance of the

FIG. 34. Common Liverwort, Marchantia. A plant, natural size, bearing female branches and cups. At lower left, a reproductive branch of a male plant. (From Sinnott's Botany.)

pistil into the seed-chamber. A small bit of living substance, the sperm, passes from the pollen tube over to the minute egg-cell within the seed-rudiment, and the seed-rudiment becomes able to ripen into the mature seed. From the coat of the seed there grow out the hairs which become the cotton.

In the summer, any seeds which have fallen on moist ground may sprout, and the young plants may grow to be two or three inches tall the first season. A great number of seedlings often spring up in a small bit of unoccupied soil near a creek bank, where they may be as close together as tomatoes in a gardener's forcing box. But very few of these seedlings can grow into good trees. The soil is usually not deep enough, or it dries out in mid-

summer, or else it is washed away by a spring flood of the following year, or perhaps the ground becomes grown up quickly with sturdy weeds which shade and crowd out the young and tender tree seedlings. If no one of these unfavorable conditions arises, there comes the struggle among the seedlings themselves for light and moisture. Only a few survive.

Streamside Plants of Plains Region and of the Mountains

Streamside plants are not the same on the plains and in the high mountains. Temperature and soil conditions are too different. The streamside plants of the two regions are, however, much more alike than are the plants of dry ground. Thus, one may find blue violets near mountain streams, and also along the creeks of the plains. It is the same with the false Solomon's seal, which seems equally at home in very different altitudes, if only it can have enough moisture, a certain amount of shade, and a moderately rich soil.

The golden pea, or thermopsis (Plate II) is one of the conspicuous plants of ditch banks and streams in the plains region. The plants are sometimes called "wild sweet peas", but this name is better reserved for the blue and purple-flowered vetches which are more like the cultivated sweet pea. Bright yellow flowers with dark green foliage are always handsome, but the golden pea is especially noteworthy on account of the compactness of its flower clusters and the large size of the individual blossoms. To the botanist, the flowers are interesting because of the arrangement of the stamens. Most flowers of the pea family have the same number of stamens, ten in all, but nine of them are united below, and the tenth is left all alone, like the thumb of a mittened hand separated from the fingers. In the golden pea, however, all the stamens are separate, as are the fingers of a hand wearing a glove, instead of a mitten. So, while the flower is, in general, pea-like, there is this one clear difference between it and that of other peas, whether wild or cultivated.

Golden peas, in the plains region, are able to grow only near ditches or streams where a constant supply of soil moisture always is available, but in the higher mountain and foothill districts they can flourish on exposed hillsides or in open groves of aspens. Like other plants which need considerable moisture,

they secure it at low altitudes in the seepage of running streams or of north slopes. Higher in the mountains, almost any situation will serve, because of the greater rainfall and less evaporation.

The bank of an irrigating ditch is a favorable place for plants to become started. There is moisture a-plenty, and from time to time washouts occur, or the owners indulge in a thorough ditch cleaning, after which there are bare places where all plant comers have an equal chance. So it happens that a ditch bank

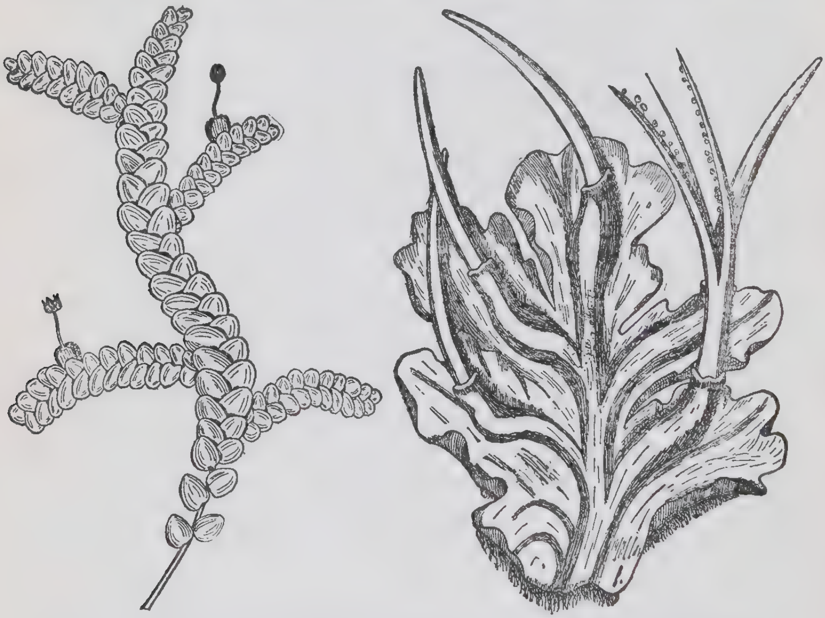


FIG. 35. Leafy Liverwort (at left). Enlarged four times. (From Sinnott's Botany.)
FIG. 36. Horned Liverwort (at right). The "horn" is the capsule which contains the spores. Drawing enlarged four times. (From Sinnott's Botany.)

may have a number of pioneer plants, just as do roadsides. Yellow dock, yarrow, snow-on-the-mountain, and other hardy weeds are likely to establish themselves here and there, and they may be able to crowd out the ordinary grasses and flowering herbs which were present before. Along older ditches, where trees have grown up and where there is abundant shade, the vegetation becomes nearly the same as that at the side of a natural creek or river.

The Different Kinds of Trees

In the plains region, the common cottonwood—the one with broad heart-shaped leaves—grows everywhere along streams and ditches. Willows of various species also fringe the bank. Alders are scattered in the moister places. Box-elders may sometimes be found but are not common. All of these different trees together form, as a rule, only a narrow belt along the streambank.

In the canyons of the foothills, there are other kinds of trees the seeds of which are continually being carried by wind or water to the plains country. Occasionally these seeds sprout, and so one of the mountain trees may, at a later time, be found growing in the plains region; but this is a rare occurrence. For the most part, the trees which are native to the mountains do not thrive so well at lower altitudes, where the climate is dry and the extremes of heat and cold are so great.

Xerophytes of Streamsides

Floods may, at times, carry down great deposits of sand and gravel, which cover up and kill all plants along a creek bottom. This sand and gravel furnish very poor conditions for plant growth; they dry out rapidly after a storm, and leave the roots of plants without moisture. Hence, after a flood and the deposit of such material, it requires many years for the bottom-land to bear more than a very scanty covering of vegetation. If cottonwoods or willows become established in a series of favorable seasons, there is enough shade on the ground from these trees to keep the soil from drying out rapidly, and then various herbs may find conditions favorable for growth. But the herbs whose short roots do not penetrate into the moist soil below, are dependent on favorable seasons, and may be killed when the weather is hot and dry. In such places, there will exist various xerophytic species—those so constructed that they can endure extreme dryness—plants with hairy stems and leaves, as some kinds of sagebrush, or else plants which are succulent, that is, fleshy and full of juice, as the prickly-pear cactus.

North- and South-facing Slopes

Creeks and rivers of the foothill country flow through steep canyons or gorges. In such places, there is very little true streambank. The sloping or abrupt canyon walls bear drought-

enduring species on the south exposure, and shade plants where facing toward the north, with a still different flora upon the streambank.

Differences in north-facing and south-facing slopes of a canyon are often well marked. A study was made of Boulder canyon in the summer of 1923 by Arthur C. McIntosh, at that time a graduate student in the University of Colorado. The accompanying tables (I and II), prepared from his observations, show the striking differences in environmental conditions in various altitudes and exposures.

TABLE I. Mean Soil Temperatures at Depth of Six Inches, Recorded from Stations at Different Altitudes in Boulder Canyon; July and August, 1923.

Altitudes	*South-facing Slope*	*North-facing Slope*
5,500 feet	78 degrees F.	63 degrees F.
7,100 feet	66 degrees F.	53 degrees F.
8,800 feet	60 degrees F.	46 degrees F.

TABLE II. Comparison of Air Temperature, Soil Temperature, and Soil Moisture per cent at Six Inches Depth, of Two Stations at Altitude 7,100 Feet in Boulder Canyon; July and August, 1923.

	South-facing Slope	*North-facing Slope*
Mean air temperature	67 degrees F.	63 degrees F.
Mean soil temp. at 6 in.	66 degrees F.	53 degrees F.
Mean soil moisture, at 6 in.	7.5 per cent.	13.5 per cent.

COTTONWOODS, WILLOWS, AND THORNAPPLES

Close to the stream, as a rule, there are willows—just a narrow fringe—and cottonwoods. The cottonwoods of the foothill area are chiefly the narrowleaf and lanceleaf kinds. The broadleaf cottonwoods of the plains find it too cold or too shady in the canyons, and even the box-elder is not much at home there. In place of these, certain foothill and mountain trees occur. Species of thornapple, or hawthorn, abound, and form a charming picture when in full bloom in late spring. Their abundance of white flowers, so fragrant even out of doors, make the streamside as attractive as a plum orchard.

The thornapples (Figs. 33 and 122) deserve more than passing notice, because of the great interest taken in them by botanists. At the beginning of the 20th century scarcely more than 50 species of this genus (Crataegus) were recognized in the eastern

United States. At the present time, over 300 are known in the same area. The supposed few highly variable forms are now seen to be a large number of species, definitely unlike one another in certain small particulars. Since, however, the differences are constant, the several forms are to be regarded as true species.

Thornapples may differ from one another in such minor points as the fuzziness of the flower-stalks, color of stamen-tips, or relative length of leaf-stalk and leaf-blade. The different species seem not, however, to intergrade. One who is familiar with the thornapples of Colorado can tell the different kinds apart, as a rule, by the fruit alone, sometimes by an examination of the flower, and often by study of leaves and twigs, with neither fruit or flower at hand. Botanists who have given no study to thornapples are inclined to be annoyed by the fine distinctions of species that are now made; indeed they sometimes ridicule the specialists who, with keener vision than they, are able to recognize such minute differences.

About ten species of thornapple are known now in Colorado but more careful study may disclose the presence of more. All of the Colorado thornapples seem to grow naturally along streams; they do not get far away from running water. It is seldom that any occur in the true mountains; they are essentially plants of the foothills, confined chiefly to canyon mouths and moist hillsides at an altitude of from 6,000 to 7,000 feet above sea level.

THE LESS COMMON TREES OF STREAMBANKS

After cottonwoods, willows, and thornapples, the other trees of consequence along streams are birches, alders, and chokecherries. All of these extend well up into the mountains and are nearly always in humus soil along creeks, where they secure a moderate amount of moisture. Under these trees and under the thornapples in rather dense shade may be found violets, false Solomon's seal, water-leaf, and meadow rue,—plants which need loamy soil with a certain amount of shade.

The Rocky Mountain region has very few nuts or wild fruits which are edible. Plums, the ordinary wild ones such as grow everywhere along streams in the Central States, are found close to streams at canyon mouths. They are, however, so few in number that the entire crop may be eaten by birds even if allowed

by the ubiquitous small boy to turn a bit yellowish or red from the original deep green. Then there is a fungous disease known as "plum pocket" which sometimes attacks the fruit, turning it into a very uninviting black mass, so that the product of a large district may be spoiled. Wild hazel bushes abound at canyon mouths but they bear few nuts, and Colorado children have no knowledge of the pleasures of "nutting".

FIG. 37. A Sedge of the genus Carex (at left). This species often grows half-submersed in shallow water at the edge of ponds. Staminate and pistillate spikes are shown; the latter are broader.

FIG. 38. Bitter Cress, or Cardamine (at right). A white-flowered plant of mountain brook-banks. Not found at lower altitudes.

LIVERWORTS, MOSSES, AND HORSETAILS

Among the small plants of streamsides which need mention, are the liverworts, mosses, and horsetails. These will be considered again in the chapter on "The Flora of Colorado", but any account of the plants along stream borders should tell something of these inconspicuous, yet interesting, elements of the vegetation.

The only kind of liverwort in Colorado which is at all abundant, is the same one which is found nearly all over the world in

shaded situations on rocks, if moist enough, and on wet loamy soil, (Fig. 34.) It is often called "common liverwort", although it is technically *Marchantia polymorpha.* The genus name is derived from that of a French botanist of the 17th century, Nicholas Marchant. The second part of the scientific name means "many forms", because the plants occur in such different shapes and sizes.

The common liverwort looks something like a rough, dark green leaf lying flat upon the ground. Upon the upper surface of the plant body there are often to be seen certain small cups, which contain many minute biscuit-shaped structures. These bodies may be thought of as buds; each one is capable of growing into a new marchantia plant, if it falls upon good soil and is kept from drying. Marchantia spreads freely by growth and branching of the plant body, so that it would seem that these cups with their buds are hardly necessary. Yet, in nature, there is often some such provision to make assurance of continued life doubly sure.

The two methods of reproduction already mentioned are both successful, but the marchantia has still another way to perpetuate the species. This last plan involves the production of female and male receptacles, which appear as small umbrellas a half-inch tall, growing up from the surface of the plant. The female receptacles are produced on certain plants, and the male receptacles on others. Below the outspread portion of the umbrella of the female receptacle, there develop the true female organs, or egg organs. These are flask-shaped, and too small to be seen except with the compound microscope. Each contains a minute egg. Within the male receptacles are the male organs, each with hundreds of small sperms.

When the male and female organs have matured, the former burst open, and the sperms swim about in the water of rain or dew which may be present. Some of them reach the flask-shaped female organ, enter its mouth, and swim through the tubular neck to the egg. A single sperm enters the egg, which is now fertilized. The fertilized egg grows for a time, and divides again and again making a small spherical body composed chiefly of many minute spores. When the spores are ripe, they escape from the now ruptured egg organ and spore case, and if they reach suitable soil they may grow into new marchantia plants.

Other liverworts than the common one just described are rare in Colorado. (Figs. 35 and 36.) The horned liverwort sometimes is found. It has a thallus, or plant body, which is smaller than that of the marchantia. Then there are the leafy liverworts, or "scale-mosses" which look much like rather delicate kinds of true mosses, save that the thin leaves are chiefly in two rows on the reclining or prostrate stem, whereas mosses have the leaves scattered all around the stem, and the stem tends to be upright.

The true mosses of moist soil along streams always form dense mats, the individual plants gaining support by being associated with their fellows on all sides. (Fig. 131.) As is true with the marchantia, they spread largely by vegetative means. There are branching filaments growing along the soil surface, extending out from the plants and producing new plants if conditions are favorable. Sex reproduction also occurs and is similar to that of liverworts, the fertilized egg giving rise to a capsule with many spores which, in turn, produce new moss plants.

Horsetails and scouring rushes, one to three feet tall, often occur on bottom lands of creeks, either in sandy or alluvial soil, providing there is sufficient moisture. The appearance of the branched stems has suggested the English name horsetail; the scientific name, Equisetum (Latin, *equus*, a horse) tells us that early botanists saw the same resemblance that we do. The scouring rushes, though they also belong to the genus Equisetum, are unbranched. They are, conspicuously jointed. There is much silica in their stems and this renders them suitable for scouring. Indeed, they were formerly employed by hunters in polishing their guns and knives.

THE TRUE SPRUCES

Colorado blue spruce, or "silver spruce", is a streamside tree. It grows chiefly at altitudes from 7,000 to 8,000 feet and usually close to running water. Other trees sometimes have the same silvery appearance of the needles on young branches,—especially Douglas spruce, sub-alpine fir, the white fir of southern Colorado, and Engelmann spruce. Hence, it is not safe to conclude that some tree seen at a distance is a "silver spruce" just because it shows a silvery blue color in the younger parts. Colo-

rado blue spruce is distinguished from other evergreens by its limited altitudinal distribution, and by its extremely sharp-pointed needles. The only other true spruce in the State is the Engelmann. This may be mistaken for the blue spruce unless the cones are present. If these are on the trees or can be found under them the particular kind of spruce may be easily determined. Cones of the blue spruce are about three or four inches long while cones of the Engelmann spruce are only two inches long, and also narrow in proportion.

WILLOWS OF HIGH ALTITUDES

At high altitudes, willows form the principal streamside trees. Most of these willows are, however, so small that they would better be regarded as shrubs. A species of dwarf birch seldom more than two or three feet tall, is also found along streams, where it grows among willows. These willows and birches are much the same as would be seen in the higher districts of the Alps of Europe, below the line of glaciers and snow, or along the streams of the region of Hudson's Bay.

SEDGES AND SEDGE MOOR; MEADOWS

A growth of sedges of the genus Carex is almost always present close to streams in the mid-mountain and higher altitudes. (Fig. 37.) These plants have a grass-like appearance and are likely to be taken for grasses. They have, however, certain differences in the flowers, and a very clearly-marked difference in the stems. Grasses have round stems, while the stems of sedges are triangular. In all there are 75 species of Carex in Colorado; some grow in the lower altitudes but the majority are in the true mountain districts. Sedges tend to occupy poorly drained soil, often of acid nature, and with a certain amount of humus. They are seldom found in sand or gravel. Streamsides of the higher mountain districts seem to afford just the environment which they need.

"Sedge moor" is the name applied to a plant community made up largely of sedges, provided the soil is wet and somewhat acid. Very wet moor may be called marsh. A large amount of moor and marsh exists in the mountains, especially near the borders of streams. The moors are not usually of wide extent, because valleys are narrow, but they make a conspicuous part of

the vegetation in the higher mountain parks, and form at least a fringe here and there at the sides of creeks and brooks. Moorland is often called meadow but, properly speaking, a meadow has grasses rather than sedges, is better drained, and the soil is not acid.

The moors of the higher altitudes have within them, as species quite inferior in number to the sedges, a few plants which are likely to be seen again and again. Common among these, are the shooting-stars (Plate I), very much like the cyclamen of florists, the white-flowered marsh marigold, globe flower, little-red-elephant, rose crown, and king's crown. These same plants occur also around lake margins, so that they are mentioned again in the chapter on "Mountain Lakes". A tall species of chiming bells (or Mertensia) is quite abundant, more common along streams than around lakes. Then there is the bitter cress (Cardamine), which seldom grows except at the borders of mountain brooks. The bitter cress (Fig. 38) is a good indicator of altitude. Wherever it is seen, the observer may be nearly sure that the altitude is 8,500 feet, or greater. It is a high-country plant, not found on the plains or in the foothills.

Streambank vegetation is, in many places, closely related to that of meadows. On gently sloping banks, such plants as grow in mountain meadows may be found. At bends in the creek there is usually an accumulation of humus soil on which grasses and flowering herbs are abundant.

In high altitudes, at timberline and above, there is no distinction to be made between the plants of streambanks and those of ordinary moist seepage areas. Indeed, the streams are often so poorly defined that it is difficult to locate them with exactness. Their position depends upon the particular snow banks which happen to be melting at the time. At the sides of even these intermittent or temporary streams, there may be found plants already familiar to one who has examined the streams in the lower parts of their courses. Many of the streamside plants in those less elevated regions seem to have worked their way down stream in the cold gulches.

FROM CANYON MOUTH TO ALPINE HEIGHT

A most interesting trip is to follow up the course of a creek or river from the plains, through the foothill canyons, and into the

true mountains. This is easily done, because automobile or wagon roads extend up most of the principal streams. It is quite out of the question to claim a knowledge of mountain plants unless one makes just such a trip. Here, in a single day, plants of such different habitats and different modes of life are passed in review as could scarcely be seen in a journey of two thousand miles up the Mississippi River from New Orleans to St. Paul. It is possible to travel up some of the canyons by rail or in a sightseeing omnibus —and either of these ways would be better than not to make the trip at all—but if one really wishes to become acquainted with the varied plant life of the Rocky Mountains the trip should be taken in a private automobile or, better still, on foot.

On such an excursion, frequent stops should be made to examine closely the plants which are being passed, else one may fail to see the flora changing with the altitude. As a rule, the modifications are so gradual that they are not noticed at all unless looked for. One by one, certain species of the lower altitudes drop out; less frequently a true mountain plant comes into view. At 9,000 feet altitude, there will be hardly a single kind of plant the same as was seen at the beginning of the journey on the plains. Furthermore, the total number of species will be very much less in the high districts than at canyon mouths.

Types of Streamside Vegetation

One way to appreciate the changes in streamside flora at different altitudes is to make note of the plants at a few definite stations scattered from plains to mountain top. For this purpose, it will be sufficient to indicate the nature of the flora at certain points typical for the several life zones. The following lists show the more characteristic features of vegetation at different altitudes. They are not complete; in fact, they are purposely made short. Although applying fairly well to any part of the State they are based chiefly on study of the region about Denver.

Streamside of plains region. The soil is often rather sandy; it lacks humus, because from time to time the vegetable matter may be washed away. Common herbaceous plants along the creeks, include willow-herb, mints of various kinds, wild rye and other "pioneer" grasses, horsetails, and scouring rushes. Where there is an accumulation of humus, a blue-grass and clover meadow is the usual plant community, sometimes with dandelions, timothy, and other plants which are familiar because so often associated with man. The trees are cottonwoods and willows, with occasional box-

elders and hackberries. Virginia creeper and wild grape may clamber on some of the trees.

Streamside of foothill region. In the more open parts of the course of a stream in the foothills, many plants are the same as those listed for the plains region. In narrower places, however, the dense shade of canyon walls gives opportunity for a different set of plants to appear. Lichens make splashes of color on the rocks, mosses are abundant, forming a dark green felt on moist stones and on the ground. The common liverwort finds suitable soil, and may grow well, although hardly with the luxuriance which it shows in more humid climates. Willow-herbs are found here, and the wild spearmint, but not the other mints of lower altitudes. Fireweed occurs somewhat sparingly in cool and shaded spots, in contrast with its abundance in both shade and sun at higher altitudes. Under trees, and in thickets close to the water, there are both white and blue violets. The trees and shrubs of the streamside are: narrowleaf poplar, various willows, alder, birch, thornapples, choke-cherries, Colorado blue spruce, Douglas fir. Patches of blue-grass and clover meadow exist where the soil contains humus. Shrubby cinquefoil may be abundant in good soil which is somewhat shaded.

Streamside of the montane region. Sedges are, in this altitude, the commonest plants near water. Buttercups of a few species abound, especially in new growths springing up on freshly exposed banks. Chiming bells, bitter cress, and little-red-elephant are found near the water. Mosses and liverworts are hidden among the sedges. In early spring the white-flowered marsh marigold is conspicuous. Engelmann spruces are the only large trees; willows and alders are of small size.

Streamside of sub-alpine region. There are many sedges, some very different from those of the montane zone. Liverworts are no longer common, but mosses are found with the sedges. Chiming bells continue, and the marsh marigold is more frequent than in the montane zone. Indian paint-brushes,—yellow, crimson, and red,—are abundant in the meadow near the sedge moor; lichens are present on the ground. Engelmann spruces are the chief trees; with them are willows, so dwarfed that they are now only shrubs.

Streamside of alpine region. Vegetation is much like that of the sub-alpine zone. The beautiful Parry's primrose is attractive in appearance, but of disagreeable odor. Rose crown and king's crown show their handsome red flower-clusters. Some other plants are the same as in the sub-alpine zone, but the total number of species is greatly reduced.

Plate III

Chapter 6

MOUNTAIN PARKS

Mountain parks are level or rolling areas confined by foothills or mountains. Most of them are merely broad valleys formed by stream-erosion and infilling; some are the beds of ancient lakes, long since drained; still others occupy areas filled by ice-masses in a pre-historic age,—valleys scoured by moving glaciers and then covered with a layer of morainic gravel and pulverized rock. Whatever their nature geologically, they are to be thought of botanically as enclosed prairies, shut off from other prairies by high hills and communicating with the lowlands through a creek- or river-gorge down which flows a mountain stream. Because they are so shut in, the rain-fall is slight, and chiefly dry-country, or xerophytic, plants make up most of the flora.

The best-known parks in Colorado are at altitudes of from 7,000 to 8,000 feet above the sea. Some smaller parks are even higher. Because of this elevation, park plants are similar to those of the upper foothill region. The parks are rich in flowering herbs, for they seem to have gathered to themselves the various kinds of plants that belong to the surrounding hills, and also many from lower stations. The plants furnish so much of beauty that the parks lose a large part of their charm with the fading of autumn.

Park Vegetation

The large parks embrace great stretches of grassland, with sagebrush, greasewood, and rabbit-brush, either alternating on different slopes or somewhat mingled. Groves of aspen trees, with usually a sprinkling of pines, occur here and there. In the gulches or along streams the usual willows, birches, and alders make either thickets or open forest fringes, while grassy meadowland or sedge moor spreads along the alluvial lands, flanking the meandering streams as they flow gently to the park outlet.

Plate III. Plants of Dry Situations. *M.* Loco (Aragallus or Oxytropis); *N.* Golden Aster (Chrysopsis); *P.* Gum-plant (Grindelia); *Q.* Gilia; *R.* Ball Cactus (Echinocactus); *S.* Prickly-pear Cactus (Opuntia).

SOME INTERESTING PARKS

Colorado has four large parks: North Park, South Park, Middle Park, and San Luis Park, each of many thousand acres. Besides these, there are actually hundreds of smaller parks. Most of the parks have a cool climate and so have been used largely for grazing and the growing of wild hay rather than for agriculture, but the irrigated parts of San Luis Park produce good crops of small grains, alfalfa, potatoes, and sugar beets.

The parks which occur along the Platte River in its course through the mountains toward Denver are small, but no less

FIG. 39. Bluebell, or Mertensia (at left). This is a dwarf species of mountain parks. It blooms early in the spring. (One-half natural size.)

FIG. 40. Wild Candytuft (at right). One of the earliest flowers of spring in open grassland and on ridges.

interesting. Other small parks are scattered here and there through the mountainous portions of the State. (Fig. 11). Estes Park, a widened valley of the Big Thompson, one of the tributaries of the Platte, has long been known for its healthful climate, beautiful scenery, and interesting wild life.

The Rocky Mountain National Park in northern Colorado is not a park in the geographical or botanical sense. It embraces a number of small parks, some very high mountains, a portion of the Continental Divide, snow fields and true glaciers, with many

lakes of rare beauty. The total area is 400 square miles, and elevations range from about 8,000 to 14,000 feet. Every sort of plant community belonging to these altitudes is found within the park limits.

The Mesa Verde National Park in southwestern Colorado, has about 75 square miles. It is visited chiefly for the cliff-dweller remains, but is full of botanical and scenic interest. Most of the park is at an altitude of from 8,000 to 9,000 feet; the climate is arid; water, even for drinking, is scarce. The name is Spanish, and means "Green Hill", but the color is bluish-green, due to long stretches of pinyon pines and cedars, with alternating dry-soil grasslands. A mysterious charm envelops this land of ancient peoples, where rows of cedars cast black and purple shadows on the red earth, and where cool mountain breezes stir the flowers of nodding gilias (Plate III) and make them show their pinkness on the background of greenish-gray.

GRASSLAND OF THE PARKS

The soil of mountain parks is often rather fine-grained in texture and is therefore suitable for grass. Where grasses form a sod they keep out trees. No doubt the rich grass growth is one of the chief factors in making the parks "open country". At any rate, the rocky ridges are clothed with forest. Tree seedlings must have shelter in their earlier years. When protected by a neighboring rock they have a better chance to survive than if exposed to wind and bright sunlight. Besides this, the soil is moister at the edge of a rock because the rain, being unable to soak through, runs off to the sides. This extra moisture is important for a young tree when it has not yet developed much of a root system.

It has been claimed that forest fires are responsible for the treeless condition of the parks, but it should be noted that fires spread more rapidly up hillsides than they do along level stretches. Hillsides in the mountain country clothe themselves with forest after a fire and no permanent treeless condition exists; level stretches, after being burned, tend to produce areas of grassland. The tramping of bison in the early days is sometimes thought to have killed the trees of parkland. Bison may have had some influence on the development of parks. Certainly, over-grazing by

cattle is very destructive to trees. Yet, after all, it is safest to say that competition with grasses is really what keeps out trees from the parks, and that fire and other agencies are of only secondary importance.

FIG. 41. White-flowered Marsh Marigold. An early spring flower of mountain marsh and sedge moor.

PARK GEOGRAPHY

Usually many mountain brooks converge to form the main stream of a park. Plants from higher ground can easily migrate downward to the park along some of the water-courses; and many up-country species are found in the moist soil of streambanks.

Communication with the low country is more difficult. This is because high hills intervene everywhere, except in one place—the river-canyon. So, while there are many avenues for migration of mountain plants into the park there is only one way for low-country plants to come. Yet with all this difficulty of reaching the park from below, the low-country flora is well represented, especially in the drier parts of the park: the open grassland, the ridges, and exposed hillsides.

Colorado belongs to the "great dry country" and few places in the State offer views of green meadows and winding streams. But the meadows of the mountain-park are most beautifully green. Even to late summer the color continues, and there is a sharp contrast with the dull gray or brown of hillsides and the whiteness of distant snow fields on the alpine peaks.

To climb out of the park, up the side of one of the inclosing hills, and then to look back, is to gain a vision of pure delight, —broad sunlit grassy parkland, shallow flower-strewn gulches, and rolling hills of scattered pine and aspen. Beyond all this, across the park, are the foothills which form the park boundary opposite. The creek is a silvery thread winding slowly toward the canyon at the outlet of the park. Upward to the snowy range are many small valleys, marking the mountain water courses that converge below. In this higher region, grows the heavy black timber that makes the somber sub-alpine forest of spruce and fir.

Trees of the Park

Pines are the trees of the park itself, and they occur also on the surrounding hillsides. The more level areas support very little forest growth. They form, as was stated, an "open country". But the low ridges and the hollows may have charming groves of pine and aspen.

Willows and alders fringe the streams, and there are birches too; although not the white-barked paper birch of the Eastern States. All of these deciduous trees are small. Winters are too long and the warm season too short for them to make large growth. So, north-country trees are best represented, such as grow in Canada and Alaska. The evergreen pines and the Douglas fir belong to this hardier race. They grow large in the mountain parks as

FIG. 42. Harebell, or Campanula. A common blue-flowered plant in open grassland of mountain parks. It is abundant even above timberline. In the foothills, the harebell occurs in shaded situations.

they do elsewhere, although, because of short seasons, it may take a century or more for the trunk to become a foot in diameter.

When pine forests in New England are cut down, a "second growth" of poplars and birches soon springs up, then later many

other deciduous trees appear. But after a pine forest in Colorado has been destroyed, if a new forest arises, it is likely to be made up of pines again. The forests of the mountain parks are plant communities of rather stable character, although after fires they may be temporarily replaced by aspens. Pine trees are present because best suited to the environment; so other kinds of trees do not often come in even when given a chance.

Quaking Aspens

Quaking aspens, or trembling poplars, no larger than apple trees, form groves scattered through these mountain parks and also make fringes along the boundaries between the grassland and the forests of pine. Even with the slightest breeze there is a rustle among the aspen branches. This is because the leaf-stalks are flattened at one end up-and-down, while at the other end the flattening is sideways. So, however the wind comes, the leaf flutters. It is a common belief that the leaves of the quaking aspen are always in motion. But one does not need to be a botanist to know that sometimes they are still. A walk through an aspen grove some calm afternoon in summer will show that without wind there is no leaf movement. As a breeze springs up, the outer leaves tremble lightly and with increasing wind the motion is caught up by the other foliage and soon every leaf is quivering. The sunlight, striking at different angles, is reflected back in glints and flashes; the whole grove is alive with action and the fluttering leaves make a noise as of pattering rain-drops.

The location of quaking-aspen groves depends on good soil and moisture. Often somewhat "springy" is the soil where the aspens grow. These trees do not thrive in the drier places which suit the pines so well. Other plants also grow in this moister soil. In the shadow of the aspens may be found many a flowering herb for which one would hunt in vain on the dry ridges or among the pines. Here are cranesbills, meadow rue, columbine, and mariposa lily, abundant in the shade, yet quite absent from the bright sun of the dry grassland.

Alders and Birches

Just why the alders and birches do not form groves like those of quaking aspen is not easy to tell. Very likely they do not spread as easily from the roots as do the aspens; at any rate, they

FIG. 43. Sulphur Flower. Abundant in dry grassland of mountain parks and foothills. The plant is named from the sulphur-yellow color of the flowers. Forty-nine other species of this genus (Eriogonum) occur in Colorado. Many of these have dull and inconspicuous flowers.

are confined to the creek-banks and to seepage areas. It may be that they require a more constant supply of moisture than is needed by the aspens, or perhaps they are unable to compete with

the grasses of hillside and level stretches. In wet soil along streams, the alders do, in places, occur in close thickets difficult to penetrate, and these are about the only examples of dense tree growth which the visitor to Colorado mountain districts will find, unless he enters a thick young forest of lodgepole pines which has sprung up after a fire.

THE CHANGING SEASONS IN MOUNTAIN PARKS

That the aspect of nature changes with the season is a matter of common knowledge, yet we do not always think of this in considering the mountain districts. Most people who spend a few weeks in the hills go there in midsummer. Though they are in the mountains year after year it is always at about the same season. With the glow of July or August all about, it is hard to realize that these green hills and blossom-covered undulations, were but dull brown in June, and that huge drifts of snow gathered on the east slopes and filled the gullies as late as April and May.

The idea that spring begins with March, and that summer starts with June must needs be modified for our mountain districts. In the higher parks, spring begins about May 15 and continues six weeks, summer extends from July 1 to August 15, autumn starts about the middle of August and lasts also for six weeks. Botanically speaking, the rest of the year is winter.

Boulder Park, at Tolland, Colorado, may serve as an example of one of our higher parks. Here there is perhaps just a touch of spring in April or May, but most of the vernal flowers show first in June, when chickweeds, catspaw, early grasses, and dry-soil sedge come into blossom. It is even later than this in some years that the pussy-willows begin to show, and the aspens may not put on their full foliage till Independence Day.

Summer is slow in coming, but when once arrived, there is a mad rush of all green things to get into bloom and to ripen seeds before winter. It is because of this that there are so many kinds of plants in flower at once. Blossom-time, which may spread over six months on the plains, is here crowded into as many weeks. Indeed, during July, there are so many flowers at once that it is difficult to see more than the mixture, just as in an oriental rug the individual colors are lost in the blended harmony of the whole.

As those who appreciate art, love to examine the details of

a piece of sculpture or of a painting, and thereby enjoy more fully the work of a master, so the student of nature takes pleasure in the parts of a landscape much more than the ordinary wayfarer. His knowledge of trees and shrubs, and of the smaller flowering plants, give added enjoyment to almost any outdoor scene. He sees why, because of soil or exposure this plant is here, that plant there,—there is a meaning to it all. That which to others is but

FIG. 44. Gaillardia (at left). A handsome composite having flower-heads with orange-yellow rays and maroon center. A plant of aspen groves, forest openings, and open grassland.

FIG. 45. Aster (at right). A purple-flowered plant of moist meadows. About 50 species of Aster are found in Colorado. All of them bloom rather late in summer. They are easily told from mountain daisies by their fewer ray flowers.

a clump of trees, is to him, perhaps, the remnant of a once mighty forest or mayhap the precursor of some new plant community that is yet to be.

EARLY SPRING FLOWERS

Early spring is always interesting, even though the weather be far from mild. In our mountain parks, an April or May breeze often seems a blast from the frozen North. Yet with all the rawness of weather, one still enjoys the bluebells and wild candytuft of the open parkland, the pasque-flower on the hillsides, the marsh-marigold and buttercup of the wet meadows. (Fig. 41.)

Very early, on open ridges, the Oregon-grape is noticed with its holly-like leaves and yellow flower-clusters. Soon afterward, under the pines, the small pink blossoms of kinnikinik may be found amid its thick leathery leaves which, like those of Oregon-grape have survived the winter. Aspens and alders come into leaf, and the willows of the streamsides. But the nights are still cold, and few of the handsome flowering herbs blossom before July's warm days. In eastern woods, the trillium, wood-anemone, and hepatica come out before spring arrives. Thus they have the direct sunlight that is cut off later by tree-foliage. Colorado plants need not hurry in order to get their share of sunshine. The pine trees have about the same number of leaves at all times, the open country is always light, and the broadleaf trees are so few that they affect but little the habits of the general plant population. Yet the growing season is short, and only such plants as grow rapidly will mature seeds and perpetuate their kind.

THE FLOWERS OF SUMMER

It is July which brings forth the conspicuous flowers. Blue columbines on north slopes, harebells (Fig. 42) in stony ground, loco-weeds (Plate III) and stone-crop in sunny places,—all are abundant. The red loco covers wide stretches, acres in extent, conspicuous from any vantage point within the park on the surrounding hills. In the parks of southern Colorado a bushy species of pepper-grass, covered with small white flowers, forms striking masses along the roadside or in abandoned fields. Dry places everywhere become clothed with the whitish mountain sage, scarce a foot high, yet the plants so numerous as to impress their pale blue-green upon the whole landscape.

Yes, with the blooming of red loco-weed, summer has arrived! The dry parkland proclaims this season of flowers by its broad patches of loco. But while the loco is beautiful when seen in the mass, it is of even greater interest if the various plants are looked at by themselves. Although the loco is a crimson-pink, it is much more than that. Some flowers are purple, others blue, or even green. There are dark shades and pale tints. Cream-color and even white are not unknown. In their fading, flowers are still beautiful as they progress to dark blue and then turn to dull and lifeless gray.

Then there is the sulphur flower (Fig. 43) which forms great yellow bands in moist soil some way above the water on a stream-bank, or forges a ring of gold to encircle a mountain pond. The small flowers grow in crowded umbels so that one of the plants is but a dash of yellow, with no detail unless seen close at hand. But whether the color only is seen, or the symmetrical branching of the flower-cluster, the sulphur flower is always interesting, always beautiful and satisfying.

FIG. 46. Twin-Flower. A creeping plant in groves and forests of mountain parks. The flowers are a delicate pink. This plant was a favorite of the great Swedish botanist Linnaeus. It is known to science as Linnaea.

Among the most pleasing members of the flora in mountain parks is the gaillardia. (Fig. 44). The large heads have purple-brown centers and orange ray-flowers, the latter with radiating lines and patterns of crimson. The gaillardia is well-known in the foothills; in the mountains it is not altered except that the plant is not so tall; the flower-heads are no smaller than those at lower altitudes, and there is the same rich coloring.

Little need be said of the columbine; everyone knows it. But how many know that it does not multiply readily from seed,

and that if long subjected to present-day ruthless destruction, it will become a rarity? It can be only through a campaign to "save the columbines" that these flowers (Plate II) will be conserved for the enjoyment of another generation.

By the middle of July, late summer flowers are in bloom. At that time the mountain daisies of many species are abundant in meadows and moist woodlands, and with them often there are blue pentstemons and larkspurs. Indian paint-brushes give color to forest openings and brown-eyed-Susans brighten the pasture lands along creeks and in wet meadows. The harebell is abundant and continues through the autumn. This plant is not confined to the mountain district but extends all the way from plains to high peaks, forming, indeed, one of the chief features of the alpine flora. While often seen in stony ground it is also found in moister situations. No doubt this ability to make a place for itself in all kinds of soil has much to do with its great altitudinal range. It is adaptable, as some people are,—equally at home in the most widely different places.

Late in the season some of the bushy composites appear. These vary in kind in the north and south parts of the State, and just which ones shall be present will depend much upon the altitude of the particular park. The individual flowers of these shrubby species are small, yet so abundant, that great stretches of open country become yellow at blossom-time. (See Fig. 25.)

Autumn in the Parks

Autumn-blooming plants of the mountain parks are few. Not to be forgotten, of course, are the gentians, asters (Figs. 85 and 45), and goldenrods, but these are few compared with the plants of summer. Yet autumn days are beautiful,—usually cold at night, but deliciously warm and sunny at noonday. Aspens on the hillsides assume various shades of yellow—sometimes turning even to bright orange; and the grasses and sedges may pass through a stage of coppery red. But all too often an early snow covers everything. When, in a few days, this melts away or dries up, most of the bright colors are gone. But the pines and firs of the hillsides are still green, and the weather may be mild through September, which is, indeed, often the most delightful month in the mountains.

THE PARK IN WINTER

With the approach of winter, snow-storms are more frequent, and the winds severe. Every sheltered gully becomes drifted full, and great walls of snow are sure to bank up the railway cuts and the depressions in automobile highways. Sleighing does not last long at any time because the roads are soon blown bare after a storm. With advancing winter, the snow continues and may reach its greatest depth in March or April.

FIG. 47. Mountain Carrot, or Pseudocymopteris (at left). A common yellow-flowered plant of grassy slopes and open groves in mountain parks.

FIG. 48. Yarrow (at right). A well-known plant with much divided leaves and grayish-white flowers. It occurs all the way from plains to timberline, and is especially common in mountain parks.

THE CHARM OF THE MOUNTAIN PARK

There can be no adequate written account of a mountain park. When the topography is described and all the trees and grasses and flowering herbs are named there are still the delicious mountain air and pure sunlight. These are forever unknown to one whose life is lived east of the Great Plains. Day after day the sun comes up unclouded over the eastern hills and shines resplendent from the great blue sky. Without moisture or dust in the air the blueness is intense. The trees cast black shadows

on the ground beneath. There is no blending of colors in the landscape. Everything stands out boldly. No haze obstructs the view. In the afternoon a shower comes up, with thick black clouds rolling into ominous mountain masses,—a few drops of rain, perhaps distant thunder, and again the bright sun and azure sky.

To one who enjoys the outdoors the mountain park is alluring, not alone in its gullies and ridges, in its wild flowers and trees, but also in its light and shadow, which, ever changing, fill the landscape with interest. The matter-of-fact man may say that a pine tree is just a pine tree. But he who studies one single pine tree knows that it is not always the same. With the times of day the shadows change, and each separate hour gives new subjective feelings. The charm of the mountain park is in green waving meadows, pine barrens and quaking aspens, loco and sagebrush—and everything more beautiful and full of interest because of the tonic air and brilliant sunshine.

Chapter 7

MOUNTAIN LAKES

When it is stated that the largest natural lake in Colorado is scarcely three miles long, the New Englander or Minnesotan will be lead to think that there are no lakes at all. But the people of the Rocky Mountain region know not the word "pond," so "lakes" may easily be numerous. Since most of the lakes are high in the mountains, surrounded by forests of pine and spruce, and have a background of snow-clad peaks, one may forget their smallness in admiration of their beauty.

Lakes in the higher mountains are usually of glacial origin. Time was, and not so very along ago, as geologists reckon, when there were glaciers scattered all along the eastern slope of the Rocky Mountains, extending down the sides of the peaks and into the valleys often to as low an altitude as 8,000 feet.

Glaciers and Their Action

A mountain glacier is a heavy and thick mass of ice which has a slow downward and outward movement due, so geologists tell us, to growth of ice crystals through melting and re-freezing of snow, and helped by expansion of ice formed when water freezes in the cracks. The chief movement produced by these physical forces is down the slopes. As the glacier moves, it pushes forward many pebbles, rocks, and boulders, while other boulders are dragged along underneath and by their grinding action dig deeper the valley or slope along which the glacier moves.

When a series of years occurs with light snowfall and much melting, the front of the glacier melts back faster than the general movement pushes it forward. So the glacier recedes, and the loose boulders which had accumulated at the front are left as a terminal moraine, which forms across the valley. Above the moraine, a lake is likely to develop, fed by the melting of the glacier.

History of Glaciers

Since the Rocky Mountains were covered with glaciers during long periods, and through many variations in climate, it is certain that glaciers were subject to a varied history. A series

of cold years, or seasons of heavy snowfall, would cause a forward movement of glaciers. With warmer seasons, or light precipitation, a general melting back or retreat would occur, and moraines would be left at former low levels to act as dams across gulches and valleys. Following this, there might be climatic variations leading to advance of the glaciers, but perhaps not to the point reached before. With the next retreat there would be another set of dams. At the present time we may recognize in places a series of moraines, indicating as many different stopping points for glaciers.

It must not be supposed that all of the glaciers moved in straight lines. Sometimes the glacier extending down the south slope of a mountain would come in contact with one from the north slope of another mountain. These might both bend to the east and flow on together as a single broad front of ice. Some of the glaciers were miles in extent and crossed the paths of previous glaciers carrying parts of the old moraines with them. So it happens that in places there are moraines running in all directions forming low ridges and shallow depressions. A district in which such conditions prevail is said to exhibit "hummocky topography".

MORAINAL LAKES

If glaciers melted suddenly over a considerable area, as would happen with rapid changes of climate, there would be dropped various deposits of morainal material here and there along the front of the glacier, and for the entire extent over which melting occurred. Sometimes ice masses would be present in the terminal and lateral moraines. With the melting of these, there would be left shallow depressions surrounded by glacial drift, forming natural basins for the development of ponds. Such areas are now frequently dry, but in the present-day vegetation there is often evidence of former ponds, long since grown up to quaking aspens or other trees of loamy soil. The presence of a great number of small ponds and lakes in a very limited area is especially conspicuous in parts of northern Colorado well known to the author. In a single half-section of land there may be ten to twenty such bodies of water.

ROCK-BASIN LAKES

Other lakes are formed by glacial action scooping out solid granite and leaving shallow rock-bottomed basins. These basins become glacial lakes, but they are of a different nature from the morainal lakes previously described. Rock-bottomed lakes in Colorado usually are small, and confined to very high

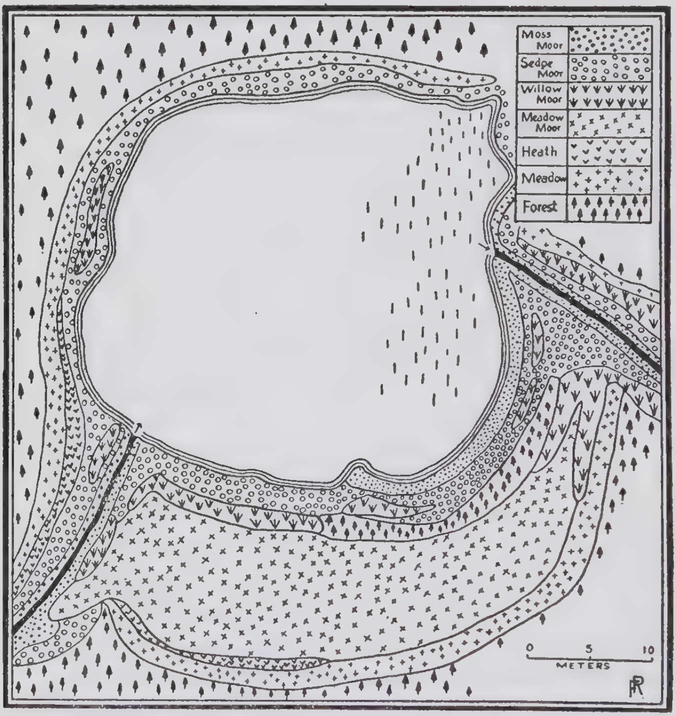


FIG. 49. Map of a small Mountain Lake (Burgrass Lake), to show arrangement of vegetation.

altitudes above 10,000 feet. In fact, most of them are as high as timberline, or nearly so. There is little growth of plants in such lakes; even the lake margins seldom have enough soil to support much pond-side vegetation. The shores are made up of huge boulders, between which coarse gravel and rock fragments are interspersed,—quite uninviting as plant habitats.

Ox-bow Lakes

The ox-bow or meander lake is met with in the plains region and in the broader mountain valleys. Such a lake can be formed only where a stream takes a winding course, meandering lazily from side to side as it flows onward. Where this occurs, it may happen that a long loop becomes separated from the main stream by a short cut-off, formed at flood time. This loop forms a lake which is at first horse-shoe shaped but may later assume almost any form by filling in of silt and vegetation. These meander lakes are of great interest from a botanical standpoint, as the rich soil of both bottom and shore permits luxuriant vegetation.

Other Lakes

Various other types of lakes occur in the Rocky Mountain country. In the foothill region some of the basins are due to wind action by which finely divided rock debris, the product of slow weathering, is blown out of a shallow, sloping valley leaving a basin in which water collects, held back by some resistant cross ledge or upturned rock stratum or dike. Some lakes have been caused by the stoppage of a stream through the work of beavers or by land-slips, or even by slight earthquake shocks which even now occur from time to time in the Rocky Mountains. Many of the lakes of the plains region adjacent to the foothills were formed by the wind hollowing out shallow basins which later became filled with seepage water from ditches or irrigated fields.

Lake Vegetation Determined by Soil and Climate

The origin of a lake has much to do with its vegetation, for the origin determines largely the texture of the soil forming the lake bottom and the shore. If given time enough, however, all lakes eventually develop a fine-grained soil, either from the washings of adjacent slopes or from decay of the vegetation which grows in the water or on the shore. The more vegetation there is, the more material for decay and the greater the production of good humus soil. New lakes, that is, those only a few thousand years old, lack the fine-grained material needed for a luxuriant development of vegetation.

Climate of the different altitudes influences the vegetation in and around the lakes of Colorado. The cold climate of the high mountains, together with the newness of the lakes and con-

sequent lack of good soil, results in sparse vegetation. Many well-known water and marsh plants of the lower country, such as cat-tails and bulrushes, can not exist in the austere environment of the mountain districts.

SIMILARITY OF WATER PLANTS OVER WIDE AREAS

Plants which grow in water are similar over wide areas. This is because conditions for the growth of water plants are much the same in Colorado as in New York or Scotland or Siberia. Water is water the world over, and unless it contains much salt or much alkali it will support an abundance of plants if the temperature is favorable. Thus it happens that the same general types of plants are represented in Colorado as elsewhere in the world. Bladderworts, pondweeds, pickerel weed, water-milfoil,

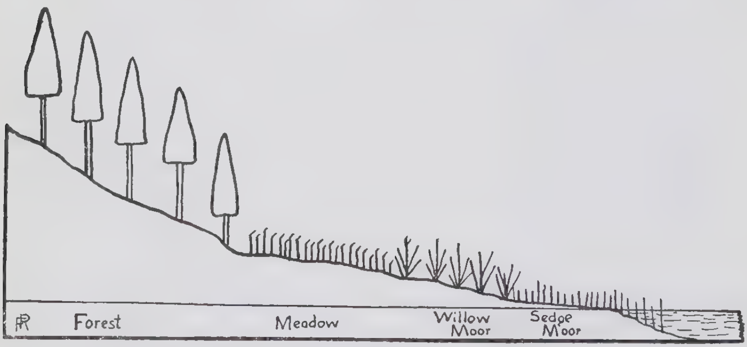


FIG. 50. Ideal Section of Shore of Burgrass Lake.

all occur in the lakes of Colorado as they do in the lakes of the Mississippi valley or of the Eastern States.

It may well be asked how water plants become so widely distributed. Often a lake has no outlet or inlet; it depends for its water entirely on the run-off of surrounding slopes or on seepage. Between it and the next lake may be miles of dry country with little chance for plant migration across from one lake to the other. The same question may come up in regard to animals, such as mollusks and water-fleas. These too are of the same species in lakes far apart.

To explain distribution of water plants and animals it seems necessary to take into account the activity of birds, especially shore birds, as sandpipers, snipe, killdeers, and the like. When

FIG. 51. Shore of a Sub-alpine Lake (Redrock Lake), showing circum-areas, or zones, of vegetation. At the lake margin is sedge moor, then a zone of shrubs (willow-birch scrub), then pine forest on higher ground.

FIG. 52. Wind-blown Trees or Wind Timber east of Redrock Lake. Most of the branches extend toward the east, away from the source of prevailing winds. (The sedge moor, scrub, and forest are seen as in Fig. 51.)

one of these birds walks along the mud of a pond shore, some of the mud will cling to the feet or legs and when another lake is visited this mud may be washed off as the bird wades around in the water. If there are seeds or the eggs of animals in the mud carried by the bird's feet these are distributed from lake to lake.

Pond-Lilies

Pond-lilies are the plants most likely to be thought of when lake vegetation is mentioned. Colorado does not have the white waterlily, hence the native who has not traveled can have little idea of the beauty of this glorious flower so familiar in the Northern States. The yellow pond-lily, or spatter dock, does grow, however, in some mountain lakes. It is very similar to the yellow waterlily of other localities but has a larger flower. The occurrence of pond-lilies may be taken as indicating a muddy bottom, or in other words that the lake is an old one, now being filled up and on its way to conversion to a mountain meadow. The lake has water which is not too cold; for very cold water is not favorable to the growth of waterlilies.

Circum-areas, or Zones, of Vegetation

An interesting feature of shore vegetation is the arrangement of plants in zones, or circum-areas. If a lake has a low-lying shore, one may expect to find bulrushes in the shallow water and also along the swampy banks. Cat-tails too may be found, especially where the soil is black and mucky. There are many small lakes or ponds in the Mississippi valley region with well-marked zones of cat-tails and bulrushes. In Colorado also, in the plains country, just such vegetation zones may be seen around small ponds. In the mountains, these particular plants do not live, but zonation is caused by other species. (Figs. 49, 50.)

Lakes at an altitude of about 9,000 or 10,000 feet often show a very regular and symmetrical arrangement of plant zones. The kinds of plants which make up the zones differ somewhat from lake to lake but a typical example may serve to show how such zonation often does occur. Redrock Lake near Ward, Colorado furnishes an illustration. (Fig. 51.)

At Redrock Lake five different plant communities may be recognized. In water of moderate depth are aquatic plants

such as regularly occur in ponds,—pondweed, bur-reed, various algae. These make up the flora of the *submersed zone*. In shallower water and on the wettest part of the shore, grow sedges and

FIG. 53. A Saxifrage (at left). This particular saxifrage is a species of the genus Micranthes. The flowers are small and pinkish-white. These plants come into blossom very early, often while there is still some snow on the ground in the neighborhood.

FIG. 54. Ladies' Tresses (at right). A white-flowered orchid found in the sedge moor and willows around mountain lakes. This is one of the 24 species of orchids known to occur in Colorado. Most of them are rare.

marsh grass. These form a distinct zone varying from five to twenty feet in width. This is the *sedge zone* or "sedge moor". Next in order is the *shrub zone* of dwarf willows and birches.

Following this, there is usually a *meadow zone* of grasses and flowering herbs, with sometimes a growth of shrubby cinquefoil. On higher and drier ground, *coniferous forest* exists, formed chiefly of Engelmann spruces, lodgepole pines, and limber pines. On the forest floor there is an abundant growth of wild blueberry, or so-called huckleberry, a low woody undershrub about a foot high with small, dark green leaves.

It must not be supposed that a zonal arrangement of plants occurs through mere chance. Zones are determined by definite physical factors which can be studied and measured. If a suitable soil borer be employed one may take samples of soil from the different zones, first weigh them, then dry them in an oven and weigh again. The loss in weight indicates the original amount of water present in the sample. Results of studies carried out by Dr. W. W. Robbins and the writer are given in Table III.

TABLE III

Percentage of Moisture in Soils at Redrock Lake

Date	Sedge Zone	Shrub Zone	Forest Zone
June 11	64 per cent	30 per cent	12 per cent
June 28	62 per cent	20 per cent	13 per cent
July 20	87 per cent	51 per cent	30 per cent
August 10	46 per cent	36 per cent	34 per cent
September 7	52 per cent	9 per cent	15 per cent
Average	62 per cent	29 per cent	21 per cent

It is also interesting to determine the soil temperature of the different zones. This is done by letting down a thermometer into holes made by the soil borer. Records at Redrock Lake are shown in Table IV.

TABLE IV

Temperature of Soil at Depth of Eight Inches, Redrock Lake
(Stated in degrees Fahrenheit)

Date	Sedge Zone	Shrub Zone	Forest Zone
June 11	34 degrees	38 degrees	40 degrees
June 28	39 degrees	43 degrees	38 degrees
July 20	52 degrees	48 degrees	43 degrees
August 10	54 degrees	51 degrees	54 degrees
August 21	52 degrees	47 degrees	46 degrees
September 7	56 degrees	54 degrees	54 degrees
Average	47.8 degrees	46.8 degrees	45.8 degrees

From the figures in Tables III and IV it is apparent that the plants of the different zones are not subject to the same environmental conditions. The sedge zone is the wettest, the shrub zone next, and the forest zone next, just as might be expected.

FIG. 55. Blue Monkshood, or Aconite. A tall plant of the sedge moor. Other species of Aconitum are also found in the State, some have blue flowers, some yellowish-white.

With regard to temperature, it is seen that the sedge zone is coldest in spring, thus making the growth season very short for plants of that zone. Later, because less shaded, the sedge zone becomes warmer than the other zones and shows a higher average temperature for the season.

It may be asked why these zones are so definite, why they do not shade insensibly into one another. The answer is, that when the shrubs once get a good start anywhere there are sure to be other plants, such as mosses, growing with them which build up the soil, making it higher than that of the adjoining sedge zone. Hence it is drier, at least near the surface. It is the dryness, or perhaps the better drainage, which shows itself in the sharp contrast of zones.

Symmetry of zonation in lakes can exist only where there is a sufficient steepness of bank. If the bank slopes very gently at any one place—so gently that it is almost level—there will be a mixture of sedges and shrubs near the water's edge and for a distance back. This very condition is found in places along the shore of Redrock Lake.

SUCCESSION

The different zones, or circum-areas, of plants surrounding a lake are not permanent in their position, for lakes are always becoming smaller, due to the down-washing of silt from surrounding higher ground, as well as infilling by the bodies of the water plants which live and die each year. The change, or progress, of vegetation is known as succession. Each of the zones presses toward the lake. The plants of the shore crowd a little way into the lake itself, the moor and shrub and meadow plants farther back crowd upon the shore zone, while plants of still drier soil press into the meadow. All of these changes take place because the soil is constantly getting drier; each species of plant extends in the direction where it will be in soil of the same moisture-content as before. The plants form a procession: they arrive at a certain spot, become established, remain for a time, and then move forward. First are the water plants; then marsh, moor, scrub, meadow, and forest. Around some lakes these changes go on quickly, especially if the supply of water to the lake becomes reduced or cut off. Other lakes persist for centuries, or even thousands of years with very little reduction in size or change in shore vegetation.

PEAT, AND ACID SOIL

The soil of moors and mountain meadows is usually of peaty nature, resulting from the decay of sedges. This lies upon gravel

to a depth of a few inches. Decomposition of the vegetable matter in the soil leads to development of an acid condition; and since mountain water is "soft", that is, has little lime, the acid is not neutralized. This quality of the soil limits greatly the

FIG. 56. Cow Parsnip, in fruit. A rank-growing coarse plant of gulches and wet ground. Much prettier in the picture than in real life. The flowers are a grayish-white.

flora, for most plants are unable to grow in the presence of acid. Many sedges tolerate acid, and their dead remains, not decaying in the acid soil, produce peat. Where peat has some depth, it may be cut, dug up, and dried for fuel as in Denmark, Ireland, and Iceland; but since in Colorado there is usually an abundance

of wood in the mountains, this is not actually done within the State. The writer has, however, seen burning peat near a railroad, where locomotive sparks had set fire to brushwood, and the fire had thus reached the peat.

Green Water

The water in mountain lakes is sometimes green, due to fine mineral particles in suspension. This color is more often seen in the sub-alpine zone than in lakes at lower altitudes. It appears with especial distinctness in certain lights and often adds a marvelously beautiful touch to a mountain landscape.

The green of mountain water is not, however, always due to mineral matter; sometimes it is caused by small plants, present in enormous numbers. These small plants belong to the group of blue-green algae and are among the smallest and simplest of all living things. When they are very abundant, as they sometimes are in lakes during late summer, they form what is known as "water-bloom". This water-bloom is not just one kind of plant but is a mixture of five or ten different species of blue-green algae: fine threads, minute spheres, or irregular green lumps of inconceivable smallness which only the compound microscope will make clearly evident. Yet these algae occur in such enormous numbers that they give a distinct color to the water. Water-bloom is common in some seasons, scarce or absent in others. Certain lakes, especially the colder ones, never have it.

When water-bloom is abundant, it may cause a bad taste in the water especially toward late summer when many of the plants die and decay. To control the growth of algae in reservoirs of water for cities the shore of the lake must first be protected from cattle and other animals which would pollute the water with organic matter. If this is done, the water-bloom will not be likely to flourish. Then a small amount of blue vitriol (copper sulphate) may be scattered from a boat. An amount of blue vitriol so small as to be harmless to human beings will prevent the growth of algae. If necessary, the treatment may be carried out two or three times in a season.

Lake Shore Plants at Different Seasons

The vegetation of mountain lake shores can best be indicated through an account of the more conspicuous plants which come

into blossom at different times. The growing period begins late and closes early; it may be divided into three seasons: spring (May 15 to July 1), summer (July 1 to August 15), autumn (August 15 to October 1).

During the period of spring there are few lake-shore plants in bloom. About June 1, or later at very high altitudes, the

FIG. 57. Fly Honeysuckle, in fruit. These shrubs occur among willows in the scrub circum-area of mountain lakes. The flowers are purplish and are followed by blackish-purple berries which occur in pairs. A valuable shrub for ornamental planting.

willow catkins ("pussy willows") appear. The brown of winter continues well into June. There are still large snow drifts in the sub-alpine forests and smaller ones in the montane zone. The soil of the lake shores is cold, and plants are slow in starting. But there is some fresh vegetation in the mountain districts even at this time. A number of xerophytic, dry country, plants have

come up and are actually in bloom on dry slopes. Of lake-shore plants, in addition to the willows already mentioned, there are the white marsh marigold and the globe flower, and one or more species of violet.

Summer brings nearly all of the shore plants into flower, and this blossoming is chiefly crowded into the month of July. Many of the sedges are early; the grasses come a little later. Spring flowers continue for a time, but are soon overshadowed by the abundance and brilliancy of the summer bloomers. In the moor, there are rose crown, shooting star, little-red-elephant, and shrubby cinquefoil, while conspicuous among meadow plants are the paint brushes, arnicas, and mountain daisies.

Autumn adds a few flowers, chiefly the gentians; these blossom about the middle of August,—sometimes earlier. Snow in many years, comes early in September but melts away soon, and a few plants, but not many, may continue to bloom until late in September.

WIND TIMBER

A feature of the vegetation at the east shore of many high-altitude lakes is the growth of dwarfed and contorted trees, forming "wind timber". Since the prevailing winds are westerly, and at times very fierce, the trees on the east shore are likely to be much bent and dwarfed because of the unobstructed sweep of the wind across the lake. Still better examples of wind timber are to be found at higher altitudes where cold and dryness are added to wind, producing a more marked dwarfing.

"MOUNTAIN MEADOWS"

"Mountain meadows" are areas near lakes and creeks, with sedge and willow and grass vegetation. Some so-called mountain meadows are really marshes, some are moors, some are dry enough and have a sufficient proportion of grasses to be true meadows. But the name is popularly used in a rather loose way. The meadows are of all sizes from a few square feet to many acres. Along certain streams there may be a series of meadows, one after another, with clumps of willows scattered as islands in a sea of sedge and marsh grass. These mountain meadows may be partially-drained marsh land of creek bottoms or sometimes old lake beds which have been filled by alluvial wash and by the

growth of vegetation. Indeed, as already explained, it is the fate of all lakes to become thus filled. Redrock Lake, the shores of which now show such striking plant zones will in time lose that zonation, and the pond area itself will be filled with sedges and scattered clumps of willow and birch. At a still later time Engelmann spruces will invade this meadow of sedges—or better, "sedge moor",—and at length a spruce forest will result. This is the climax or ultimate plant community for the montane and sub-alpine life zones in Colorado.

Chapter 8

THE LIFE OF A PLANT

So far as its own existence is concerned, a plant's relations are primarily with the soil and with the air. Both of these contribute material which the plant needs and uses. The soil supplies water and small quantities of mineral matter, while the air furnishes carbon dioxide for food making and oxygen for respiration. And just as important as these material substances, is the light of the sun which plants capture and which is the primary source of energy for growth, food making, and other activities.

The Soil

Soil is a far more interesting material than might be supposed. It is not of simple nature, for it is composed of many substances. The basis of all soil is the mineral matter in it, made of rock fragments: large, medium-sized, small, or minute,—depending on whether it is gravel, coarse sand, fine sand, or clay. In addition to this inorganic soil constituent, there is humus, which is decomposed animal or plant substance. Around each particle of solid matter, both organic and inorganic, is a thin film of water, and water may also fill up many of the spaces between these solid particles. A well-drained soil always has air in it, especially in the upper layers. If a soil is made soggy by too much water there is no room for air which is so essential for root growth.

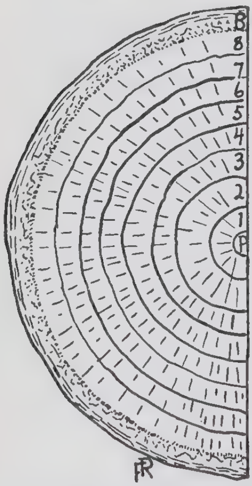
Soil Water; Absorption, Use

From the soil, plants take large amounts of water. A thrifty specimen of the common sunflower will use a quart of water a day. A cottonwood tree or the blue-grass lawn of a city lot may require many gallons or even barrels. Most of the water absorbed does not enter into chemical combination with other materials but continues to exist as water within the plant. So much water is constantly being lost through evaporation (transpiration) from the leaves, that large quantities are needed for replacement. The soil water, which the plant-roots absorb, is much like well water,—it contains only a small amount of dissolved substance.

Water is needed in the plant, not only to replace that which is constantly passing off through transpiration, but it is needed also as a necessary part of the living substance (protoplasm).

Water is required in the process of sugar making in the plant, and it is necessary as a solvent for the substance carried in the sap from one part of the plant to another. Indeed, sap is best thought of as water,—almost pure water, with only small quantities of inorganic salts in solution, and with slight amounts of sugar and other foods. Every plant is largely water; the leaves of lettuce or fruit of orange, are almost all water, the water-content in them being 90 to 98 per cent.

Just how the roots absorb water is an interesting problem, not easy to explain in non-technical terms. It may be stated, however, that water is not sucked into a plant as it is sucked into



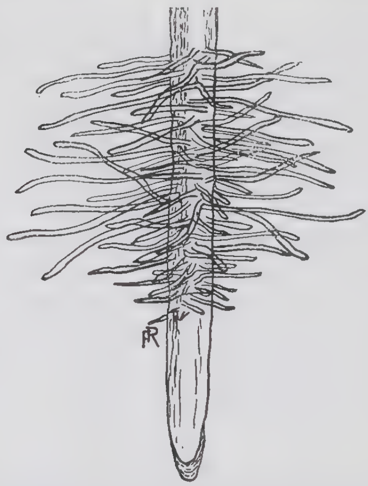


FIG. 58. Cross-section of an eight-year-old Stem (at left). *B.* Bark; *P.* Pith; Nos. *1*, *2*, etc. are the annual rings of wood. No. *1* is the oldest and No. *8* is the ring which was formed last. Growth takes place just below the bark, a new ring of wood being produced each year.

FIG. 59. Sketch of a Small Root (at right). This drawing shows the root greatly enlarged. Note the brush of root hairs which serve as absorbing organs. At the tip of the root is the root cap.

a pump. The roots do not have any visible openings through which water may enter. Young roots have a brush of delicate root hairs near their tip. (Fig. 59.) These serve as the absorbing organs, but the hairs are everywhere closed, and whatever water enters is first imbibed by their cell walls and later passed onward by osmosis and diffusion. Water enters slowly but, since the root hairs are exceedingly numerous, a large amount of water may get into the root during the course of a day. Much of this

moves with no great speed up through the root and stem, and then is lost through transpiration from the leaves. Only small quantities are employed in food making.

Roots obtain water easily from coarse soils and are able to take out nearly all of the water which may be present. They can not get so much from fine-grained soil, for this gives up its water grudgingly, and a plant may wilt in clay which contains 30 per cent of water.

MINERALS OF THE SOIL

Soil-water has within it small quantities of salts, and most of the salts are needed for the well-being of the plant. They are not foods in the ordinary sense, just as table salt is hardly a food, but they are necessary for growth and even life. The chief mineral elements required are potassium, calcium, magnesium, iron, nitrogen, phosphorus, and sulphur. Soils lacking any one of the seven necessary elements are classed as sterile; they will permit only a scanty growth of vegetation. If there is an over-abundance of soluble mineral salts, as in alkali soils, the vegetation is sure to be limited to a few plant species.

Most of the soils of Colorado have enough of each of the required mineral substances. Fields upon which the same crop has been raised year after year are still fertile, but will eventually need mineral fertilizers. For present-day agriculture the chief need of the soil is organic matter to produce humus. Humus is another name for decomposed organic matter; it is produced from straw, leaves, and barnyard manure. It improves the physical properties of the soil, keeps the soil from drying out, prevents the surface from baking or caking in the hot sun, and helps to make it easily worked by plow or cultivator.

Some soils, as already noted, have too much soluble material in them, and they are then said to contain "alkali". A soil of this kind will support only a very poor growth of plants. There are two reasons for this. In the first place, the alkali may be actually poisonous to the living material of the plant. Still more important is the physical condition of the soil water. It is so full of dissolved substance, so concentrated, that it would tend to draw water out of most plant roots. There are, however, certain plants naturally provided with a highly concentrated sap,

and some of these can live in alkali soil. Certain districts in Colorado, as in all arid regions, have considerable alkali but, on the whole, the alkali problem is not serious in the State.

Soil Acidity and Alkalinity

European botanists often classify plants as "lime requiring" and "lime avoiding", and they sometimes make long lists of wild species which occur on limy soils and other lists of plants on soil with very little lime. Here in the United States, such distinctions have not appealed to ecologists. If particular kinds of plants occur on special soils they have been thought to be there because of some other feature. And yet there can be no doubt that acidity or alkalinity of soil-water must make a great difference to plants. Recently there have been developed methods of testing quite accurately these qualities. It is likely that suitable studies will explain the peculiar local distribution of certain plants. Thus, the common cedar of rock ridges is abundant on some canyon walls or hillsides, and quite absent from others only a few miles away. There can be little doubt that soil differences are largely responsible for such curious plant distribution. Perhaps the "lower timber line" of pines near the base of mountains or mesas is due in part, at least, to chemical properties of the soil unfavorable to the growth of pines.

Gases Used by Plants

A plant is concerned not only with the soil but also with the air which surrounds it. From the air, it obtains carbon dioxide, used in food making, besides oxygen for respiration. Nitrogen, which forms about four-fifths of the atmosphere, can not be used directly by green plants, and such nitrogen as is needed for protein-making must come from nitrates of the soil.

Food Making, Photosynthesis

Food-making in the plant requires carbon dioxide and water as raw materials. The process is carried on in green leaves and stems, and, more definitely, in those parts of the living substance colored green with the material known as chlorophyll. In the presence of sunlight, that part of the protoplasm which is colored green by the chlorophyll has the power of putting together the raw materials already mentioned and of thus making sugar. The

sugar which is formed is not our ordinary table sugar; commonly it is glucose. From glucose, the other types of food needed by plant are later formed. Starch can be made from glucose by certain chemical changes, so also can fats, oils, and waxes. Even the most complex of all compounds, the proteins, are built up by adding the right chemical materials to the sugar which was first produced.

Since light furnishes the energy, the process of food making is called photosynthesis. Photosynthesis is, literally, a putting together by means of light. Light, shining on the chlorophyll, causes a "putting together" of carbon dioxide and water, with the formation of glucose. Glucose forms the basis of all of the foods made by green plants and used for growth and repair. By the destruction of foods, energy is released to carry on the various chemical processes of the plant. The light of the sun is the original source of the plant's energy. And since animals get their food from plants, or from other animals which in turn feed upon vegetables, it is clear that sunlight is the ultimate source of the food and energy of all living things. Colorado has an abundance of sunlight, so this primal energy is not lacking.

Food, when made by the plant, can be used at once for purposes of growth, but often it merely accumulates in roots, tubers or stems, perhaps to be employed at some future time, but often not to be used at all. Plants make far more food than they will ever need. If conditions are suitable, the process of photosynthesis goes on so rapidly that growth and other activities which would use the food do not keep pace. The underground parts of many plants become filled with food; examples are found in the mariposa lily, Solomon's seal, dandelion, dock, wild onion, angelica, and such common cultivated plants as potato, beet, and carrot.

RESPIRATION; A NECESSARY DESTRUCTIVE PROCESS

Besides photosynthesis, or food making, there is, as already intimated, another process which destroys food and frees its latent energy. This energy, now become active, is used to promote chemical action for the building up of those complex substances which go to make the living material of the plant. In some ways, this other process, known as respiration, is the opposite of photo-

synthesis, for it destroys while photosynthesis builds up; and yet this process of tearing-down is an unavoidable feature of life. Just as the destruction of coal is necessary to make a locomotive go, so the destruction of sugar or other foods, keeps a living plant in active operation. The slow oxidizing process of respiration which takes place in the protoplasm is very closely akin to the burning of fuel.

PHOTOSYNTHESIS AND RESPIRATION CONTRASTED

The contrasts between photosynthesis and respiration are of interest: photosynthesis takes place only in the presence of light, respiration goes on in living protoplasm at all times; photosynthesis adds weight to the plant, respiration reduces weight; photosynthesis is brought about by the light of the sun, the sun's energy is absorbed and stored in the food which is made; respiration frees energy, and makes it available for the furtherance of chemical reactions.

In the two processes there are certain exchanges of gas between the plant and the surrounding air. Photosynthesis, as will be recalled, uses carbon dioxide from the air, which it combines with water to make glucose. In this process, a certain amount of oxygen is freed which may escape into the air. During the daytime when there is light, photosynthesis takes carbon dioxide out of the air and returns pure oxygen in its place. Respiration, on the other hand, is removing oxygen from the air at all times. It requires oxygen because it is really a sort of burning process. So, naturally, one of its products is carbon dioxide; this passes off into the atmosphere both day and night. Although photosynthesis takes place during only a part of every twenty-four hour day, the process is a rapid one and every green plant uses a large amount of carbon dioxide but needs comparatively little oxygen.

It is evident that plants "purify" the air only during the day; at night they make it less "pure". Let no one, however, fear on this account to camp in the woods at night because of the "impure air" produced by the trees and other vegetation. Neither out of doors nor in the house, will the atmosphere be appreciably changed by plant respiration. So far as "impurities" produced by plants are concerned, they need not be considered at all; a

dozen geranium or fuchsia plants in a sleeping-room, since they have such a slight total weight and are so relatively inactive, do not exhaust the air as much as one human being would do.

INFLUENCE OF LIGHT

Plants have other relations to light than those involved in photosynthesis. Changes in leaf position are well seen in house plants on a window sill; many flowers open in the morning and close the petals together at night; roots of ivy grow away from the light, but ivy leaves take positions which give them full illumination. Many cultivated plants, such as the rose, do not flower freely unless they receive some direct sunlight, while other kinds of plants do very well in the shade.

"LONG DAY", "SHORT DAY", AND "EVER-BLOOMING" PLANTS

The influence of the length of day upon vegetative growth of plants and upon flowering, is often great. The common cosmos of our gardens does not bloom in the long days of June or early July, no matter how thrifty; it needs the shorter days of August and September. Other kinds of plants flower best when the days are longest,—as many cultivated flowering shrubs and a large number of native shrubs and herbs. Yet, of course, there are "ever-blooming" species and varieties to which the exact length of day seems of little consequence.

Recent studies show that "long day" plants can be made to blossom at any time of year, in the greenhouse, if given artificial light to prolong the day to the required length. Certain vegetables can be hastened for market by exposing them to electric light for a few hours daily in addition to the natural sunlight. "Short day" plants will flower, even in June, if put regularly into a dark chamber in the late afternoon, so as to shorten the length of daily exposure to light. Growth of leaves and stems also is much affected by length of day. Apple seedlings do well if the day is twelve hours long but will not thrive if exposed to light for 16 hours. Box-elder seedlings, on the other hand, do poorly in a 12-hour day but make rapid growth with longer light exposure. It is much to be desired that studies of our native plants be made, to determine the "long day", "short day", and "ever-blooming" species.

GROWTH DETERMINED BY HEREDITY AND ENVIRONMENT

So long as plants are alive they continue to grow,—if not in height, at least in bulk. In this respect they differ from animals, which attain at maturity a certain size and then do not add to this in later years. Trees grow upward year by year, add thickness to the trunk, and spread out in all directions by means of branches. The height to which a tree will grow is dependent, to begin with, upon the inner nature of the tree itself. But the height is influenced to a degree, by the available water in the soil. In dry ground, where any considerable amount of water is a long ways down, trees will not attain great height, but if the same kind of tree, an oak for example, grows in soil which is more moist near the surface, the tree will become taller. Moisture of the atmosphere also is of importance in determining the height of trees. In exposed and dry situations, trees are likely to be stunted in growth, while the self-same species growing in a protected gulch may take on a very luxuriant aspect. Thornapples, cedars, pink locusts, and Juneberries furnish examples of this behavior in the lower altitudes; in the high mountains, Engelmann spruces of wind-swept ridges show a great contrast with trees of sheltered canyons. It must not be supposed, however, that the limits set by heredity can be overcome by even the most favorable conditions. Thus thornapple trees can not possibly compete with cottonwoods, nor scrub oaks with the Douglas fir.

Any very rapid growth in plants is usually due to swelling caused by taking in of water, while slower growth is brought about by actual increase in the solid substance. When mushrooms spring up over night, their growth is but a swelling due to water absorption. The fully formed mushroom was already in the soil close to the surface, and it needed only the rain to make it swell up to twice or ten times its original size. The rapid growth in the spring of twigs of cottonwood or box-elder or hackberry is due also largely to water, but it is followed throughout the summer by substantial additions of solid material. As is well known, the fresh sprouts, so tender and watery at first, become firm and strong before winter. Sometimes perennial plants produce sprouts late in the season, and these are likely to be winter-killed because there is not time for them to develop thick cell-walls.

ANNUAL RINGS; THE AGES OF TREES

It is an old story that the age of a tree may be ascertained by counting the annual rings of wood. (Fig. 58.) Who first discovered this we do not know, but it has probably been known for hundreds of years. In moist seasons, trees make thick rings; in dry years, the rings are thin. By examining stumps of trees cut down on known dates, it is possible to learn something of climatic conditions during the years in which the trees lived. Studies of annual rings of the big trees of California are especially interesting for they tell a history of hundreds, or even thousands, of years. But the annual rings shown by our own cottonwoods, pines, and spruces are not without interest. They show years or series of years with dry weather and other periods of greater rainfall. There is a general mean, with oscillations in one direction or the other, but no indication of significant climatic change. All study so far made of annual rings tells of a rather permanent and enduring climate. There is little ground for thinking that the climate of Colorado has changed materially since the coming of the white man.

No trees in Colorado are as old as the big trees of California; yet large ones are 200 or 300 years, and a few are 400 or 500 years old. Some of the trees still standing were young saplings in the days of Columbus.

The yearly addition of a ring of wood to the trunk of a tree is necessary to supply a passage for the water needed by the new twigs and branches produced each season. Those trees which annually add most to their foliage, increase most their thickness of trunk. Such rapidly-growing trees as cottonwood may have annual rings an inch thick, while the rings of thornapple are often so thin that they can hardly be detected with the unaided eye. Engelmann spruces, in favored situations, sometimes produce rings a quarter of an inch in thickness. At timberline, however, where conditions are unfavorable, the rings may be only a tenth as thick.

Unusual conditions sometimes interfere with the regular and even growth of a tree and therefore modify the development of annual rings. A late spring frost may kill the young leaves and stop the growth of wood. When fresh leaves appear, as they do in such cases, the growth of wood is resumed. The wood formed

during the two periods will show a difference in texture; so in that year there will be two wood rings. But both rings will be narrow, and an expert, in examining the stump of the tree, could tell that they were not separate "annual" rings. The destruction of leaves by caterpillars, or by hail, may result in like manner in the development of two rings in a single season.

GROWTH FORMS; HERBS, SHRUBS, AND TREES

Differences in manner of growth and in ability of their aboveground parts to live over winter cause plants to be herbs, shrubs, or trees. By far the majority of plants in Colorado are herbs; relatively few, a hundred or so, are shrubs; hardly fifty are trees. Yet trees make such an impression upon the observer that they are often the best known.

The three groups of herbs, shrubs, and trees are not always easy to separate. Some shrubs, as species of sagebrush and grease-wood, are hardly more than herbs, for much of the plant dies down each season. Many herbs are larger and more conspicuous than such shrubs as Oregon-grape, kinnikinik, or purshia. As for intermediates between the groups of shrubs and trees, there are many. Among these, may be noted the thornapples and oaks. Even in one particular species of thornapple, some individuals would be classed as shrubs, others as trees. This same state of affairs exists among oaks, certain willows, the wild plum, and the cherry.

It is not easy to give a definition of the word "tree"; practically the only distinction from a shrub is its possession of a single main trunk. Size is not a determining feature, for there are some shrubs as tall as certain trees. It is then the growth form which makes of a plant either a shrub or a tree. The growth form is chiefly dependent upon the manner of branching near the soil line. Shrubs produce many upright stems while trees form only one. The manner of growth is determined by the true inner nature of the plant, that is, its heredity.

GROWTH IN LENGTH OR HEIGHT

Growth in length of roots and of most stems takes place only near the tips of these organs. When a twig or a root has become hard or woody it is impossible for that part of the plant to elongate. Thus, a limb of a tree which is now six feet from the ground will

be no higher up ten years hence. Fence rails and wires fastened to trees are not carried up in the air as the trees grow older.

The maximum heights to which species of plants will grow differ enormously. Many mosses attain a height of about one-quarter inch while eucalyptus trees in Australia become 300 feet tall. In Colorado, there are plants of nearly all heights up to about 80 feet. The tallest cottonwood trees are about 60 feet. Engelmann spruces, in favored spots, grow somewhat taller.

The Importance of Heredity

Heredity is always a strong, and even compelling, force with plants, just as it is with animals and men. This statement does not mean that environment is without influence, for the effects of environment are everywhere apparent. But attention can not be directed too often to the plant's inheritance.

An illustration of the conservatism of plants, in other words the influence of heredity upon them, can be seen among pines and other trees of the pine family. These trees, with their thick and well protected needle-shaped leaves, present little surface for transpiration and so are suited to dry situations. But when such trees grow in wet soil, as pines do occasionally and the Engelmann spruce does frequently, the leaf-shape does not become in the least altered. Again, as pointed out in the chapter on "Forests and Forest Trees" the cottonwoods and oaks which grew at Florissant, Colorado, some millions of years ago were hardly different from those of the present day, and yet there have been many changes of climate, volcanic eruptions, fires, floods, and other environmental disturbances.

Recent studies of heredity have made the subject much more a matter of science and much less one for speculation and guess-work than formerly. Some of the chief laws of heredity are now well known, thanks to the epoch-making studies of Gregor Mendel, an Austrian monk of the 19th century, and to more recent investigations by many workers since the year 1900.

Although a large part of the experimental work upon heredity in plants has been done upon cultivated forms, it must be remembered that all cultivated species had wild ancestors, and that most of these ancestral types still exist somewhere in the wild state. Thus, any general laws of heredity which may be discovered

will apply as well to the native species of Colorado as to plants of garden or field.

Characters and Inheritance Factors

Any living creature is made up of a combination of "characters" (features, qualities), and these are determined by "inheritance factors" in the germ cells. Thus a certain species of anemone growing in Colorado has some plants with red flowers and some with yellow flowers. Red-floweredness and yellow-floweredness are characters, each depending upon an appropriate inheritance factor in the living substance, and derived from the parent of the plant which possesses it. Up to the present, no one has ever seen one of these factors. A factor is thought to be a very small particle of matter, although not so small as the molecule or atom of the physicist.

The characters of plants, or animals, occur frequently in nature as alternatives. Thus an anemone plant may have red flowers or yellow flowers, not both; a sunflower plant is either branched or unbranched; garden pea vines are either tall or dwarf; corn has starchy grains or else sugary.

Inheritance in Sunflowers; Dominance

An interesting peculiarity of inheritance which sometimes occurs, but not always, is known as dominance. If a red sunflower is crossed with a common yellow sunflower the offspring are red, not intermediate in color between the parents. Because of this behavior, the red is said to be "dominant" and the yellow "recessive". The branched condition of sunflower plants is dominant to the unbranched. If red-flowered branched plants are crossed with yellow-flowered unbranched the immediate offspring are red-flowered branched plants, quite like one of the parents. If, however, these new plants are bred among themselves, they give rise to *red branched, red unbranched, yellow branched, and yellow unbranched.* Here, then, both grand-parental types appear, and also two new combinations, viz.: *red unbranched* and *yellow branched.* This appearance of all possible combinations in the offspring of crosses is called "independent assortment". It occurs among plant characters which show dominance, and it is found also with character-pairs in which dominance does not exist.

COLOR IN FOUR O'CLOCKS, INHERITANCE WITHOUT DOMINANCE

Flower-color in garden four o'clocks and in snapdragons will serve to illustrate heredity without dominance. If red-flowered plants are crossed with white-flowered ones the offspring have pink flowers. These pink hybrids, if bred among themselves, produce three kinds of offspring: *red*, *pink*, and *white*.

HYBRIDIZATION AND NEW TYPES OF PLANTS

Comparatively few plants have been studied fully with regard to their unit characters, but all of those which have received much attention show essentially the same behavior. The offspring of two unlike individuals often show some features of one parent and some of the other parent. If the plants of this new hybrid generation be bred among themselves, they give rise to all possible combinations of the characters which differed in the grandparents. The plant breeder, by preserving types which show desirable combinations, develops new and improved varieties. Nature also, no doubt, selects for preservation the forms best fitted to the environment. Whenever there is much inbreeding, new combinations are not likely to appear, and a relatively permanent and unvarying type becomes established.

The crossing of two different species or varieties sometimes leads to the production of new types of great value. Cantaloupes and other melons have been largely improved by crossing and selection. Some of the best plums, and nearly all of the common table grapes, are of hybrid origin. Improved varieties of wheat, barley, and rye, on the other hand, have generally been produced, not by crossing, but by selection and propagation of individual plants of special merit.

MUTATIONS

Much of the variation seen in plants is merely a recombination of characters which were already present in the parents, but there are also true variations depending upon changes (mutations) in the living substance. Good examples of such mutations are well known to botanists. One of local interest is that of the red sunflower, which was first described from a single specimen found by Mrs. T. D. A. Cockerell in Boulder, Colorado. The plant was growing wild at the side of a road, among thousands of the common yellow-flowered type. The soil in which this red sunflower grew

was not at all different from soil all around it nor did this plant receive more or less water than the other plants. Its production of red flowers was not caused by any peculiarity of the environment; the redness was due to some internal change—to something within the living substance itself. All of the red sunflowers now grown in this country and in Europe are derived from this single Colorado plant.

Another mutant which appeared in Colorado was a dwarf plant in a field of tall lima beans belonging to a Denver seed house. Unfortunately, all the descendants of this plant were destroyed the next year by a flood. The dwarf lima beans now grown in gardens are derived from mutations which took place about the same time (the early years of the twentieth century) in Virginia and in New York State.

These examples suggest that plants sometimes change in nature, that new varieties are being produced through no apparent external cause. But, on the other hand, it must not be forgotten that mutations are rare, coming only once among thousands or millions of cases. Definite hereditary resemblance is the rule, mutation the rare exception.

VALUABLE CHEMICAL SUBSTANCES IN PLANTS

A very important part of the life of a plant is its chemical nature. Nearly all plants have certain chemical substances in common, as starch, sugar, and cellulose, with small amounts of fat or oil, besides the proteins of the living substance. But some plants contain unusual materials often of considerable interest.

There is a thick milky juice called latex which is present in milkweeds, spurges, and plants of the Chicory Family, such as the dandelion. We do not know that this latex is of any special value to the plants. Apparently it is never used by them after being formed, so it is probably just a waste product. In the prickly poppy, so common along Colorado roadsides, a brilliant yellow latex occurs. The true milkweed has a more abundant supply of latex than other plants, a cut stem often affording many large drops of the white milk-like fluid.

Rubber is derived, on the commercial scale, from the latex of tropical trees; it is, however, possible to secure rubber from some of our native plants. Chief among these is a much-branched

half-shrub of the Composite Family, the Colorado rubber plant (Hymenoxys), which grows in the southern part of the State. It is not likely that our hymenoxys will ever become an important source of rubber, since the extraction of rubber from it is expensive. Present methods at least, require chemical solvents to draw out the latex, and also tedious and costly manipulations. In the end, only a small amount of rubber is secured after much expense and trouble. It is, however, interesting to know that there are sources of rubber outside of the tropics, and that if the usual supply were cut off a certain amount might be secured at home.

Medicinal Plants

Medicinal and poisonous substances occur in many plants. In fact, much of the study of botany in early times was carried on by the physician or pharmacist who wished to make use of the powerful "principles" which plants furnish. Even in the present day, much use is made of vegetable drugs, such as morphine, strychnine, digitalis, and quinine. Not one of these four drug plants is native to Colorado, but digitalis could undoubtedly be grown here by any one interested in developing a drug farm. Colorado has, however, a certain number of wild plants which contain drugs and poisons. Of these, perhaps the most familiar names are: aconite, arnica, dandelion, angelica, wintergreen, gentian, lobelia, yarrow, wormwood, mountain sage, bistort, henbane, male-fern, jimson weed, water hemlock, whorled milkweed, poisonous mushrooms, or "toadstools", larkspur, and death camas.

Aromatic Substances

The delightful fragrance of pine woods, or of spruce and balsam forests, comes from aromatic substances present in the needle-leaves and in the bark and wood of twigs. Much of the charm of foothills and mountains depends upon the production by the evergreen trees of resin, aromatic oils, and balsams. These various substances may be of some slight value to the trees as a protection from insect and fungus attacks or from injury by animals but, on the whole, they seem to be chiefly waste products without special significance. Yet they are of real value to the men and women who seek pleasure, health, or solace in communion

with nature. Certain balsams, resins, and oils are of well-known economic value, and amber is a fossil resin; but Colorado does nor furnish any of these products for commercial purposes.

The substances which give odor to flowers are called esters or fruit ethers. These are formed in small glands occurring most often near the base of the floral leaves. Some kinds of flowers produce their scent especially in daytime, others at night. White flowers, pollinated by night-flying moths, are often more highly scented in the early evening than at other times. It seems likely that odor has much to do with insect visits, serving to indicate the presence of nectar. Certain experiments show that insects will visit flowers after the bright-colored parts have been cut off with scissors. Odor, it would appear, is in such cases the attracting stimulus. Many experiments with insects, however, suggest little sense of smell, and it must be admitted that the stimuli which cause insects to visit flowers are little understood.

Fruit Flavors

The flavors of edible fruits are produced by a combination of fruit ethers, sugar, and fruit acids. But the texture of a fruit, and the amount of water in it affect greatly our opinion as to its taste. A dry strawberry seems to be of a flavor quite different from one which is fresh and juicy. Different kinds of apples have much the same chemical composition, but the texture of the flesh gives one variety a different taste from another. Wild edible fruits in Colorado are not abundant but, as noted in another chapter, there are plum, red cherry, choke-cherry, strawberry, gooseberry, raspberry, Juneberry, blueberry, and thimbleberry. Birds eat still other fruits, especially the thornapple, elder, honeysuckle, sumac, and various currants. There can be no doubt as to the value of edible fruits to plants, for birds and other animals gather these fruits to eat and often distribute the seeds far and wide. The fruit ethers, which contribute to the flavor, are important in making the fruits attractive and thus aiding in the spread of the species.

Volatile Oils are Waste Products

Such volatile oils as occur in leaves of catnip, horsemint, and spearmint, and in plants of the parsley family, are probably mere

waste products of the life activities. It is not known that they serve any useful purpose. The student of nature can often, however, distinguish one plant from another by the odor; more than that, these odoriferous substances may give much satisfaction and pleasure to one who is familiar with them.

TANNIN

Tannin is an important product of plants, occurring in great abundance in the hemlock, chestnut, and oak, and giving its useful properties to "tan bark". The scrub oaks of Colorado have little tannin, and there are no wild hemlock trees in the State. Hence tannin production is not likely to become of consequence. Small quantities of tannin exist in many trees and shrubs, partly in the bark of stems but often more abundantly in roots. The astringent taste of tannin and its peculiar action upon the tongue and mouth may be noted in tasting roots of Oregon-grape or, indeed, any one among scores of other common plants.

FATTY OIL

Nearly all plants contain some fatty oil. This is usually a food substance which the plant actually uses and is, therefore, in quite a different category from latex, resin, tannin, perfumes, and "active principles". Abundant oil exists in many seeds, where it affords nourishment to the young plant at time of sprouting, or is frequently employed by man for his own uses, as is true of cotton seed, flax seed, and castor-oil seed. Nuts contain much oil; this is true of Brazil nuts, cocoanuts, and walnuts. The cultivated grains, also, as wheat and corn, have a considerable percentage of oil. But oil is not confined to plants of economic value; it is present as the food material in nearly all light wind-distributed seeds. A given weight of oil gives twice the food value of the same weight in starch or sugar. If seeds are to be of light weight, oil has a great advantage over these other foods. The food material in the seeds of dandelion, goldenrod, and thistle is largely oil, as is also the case with seeds of other members of the Chicory Family and Thistle Family.

ACIDS IN PLANTS

Acids in plants include not only those found in edible fruits, such as the malic acid of apples and the citric acid of orange and

lemons, but also acids which give the sourness to leaves of oxalis and sour dock and sheep sorrel. These leaves contain compounds of oxalic acid in small amount. In this case, as in so many others, the peculiar substance seems to be of no value to the plant. Apparently it is just a waste product.

Calcium Oxalate

Many plants have minute needle-shaped or club-shaped crystals of calcium oxalate in their roots, stems, and leaves. Yucca, sand lily, and clematis furnish examples; there are actually hundreds of others. In the common house geranium, calcium oxalate is present in crystals of rhombic form.

Enzymes; Vitamines

Enzymes are substances concerned with food digestion and with respiration. In the bodies of men and animals, the best-known enzyme is pepsin,—best known because of much advertising by chewing-gum manufacturers. Among plants, there is an enzyme in the sprouting grain of barley which changes starch to sugar, and in all germinating seeds there are appropriate enzymes to act on the particular foods present. A fat-splitting enzyme acts upon oil and makes the oil available as food for the young plant, and a protein-splitting enzyme digests food of a proteid nature. Respiration, growth, and various other plant activities are, just as is digestion, dependent upon enzyme action.

Vitamines, so important in the nutrition of human beings, exist in certain parts of plants and give to green vegetables and fruits much of their special dietary value. These same vitamines are present in milk, the cow apparently getting them from grass and hay. If the required vitamines are lacking in the diet, a deficiency disease or some form of malnutrition develops. The vitamine present in green leaf-vegetables is important for growth of children, and the vitamine so abundant in graham crackers and in most fruits will prevent the very serious oriental disease, beri-beri. Other vitamines, although not so well known, are of undoubted importance. Nature provides vitamines in our wild fruits and in the various plants used as "greens", quite as much as in the cultivated grains or in the spinach and lettuce of the garden. Just what the significance of vitamines to the plants themselves may be is not as yet fully understood.

Further consideration of the activities of living plants and of the substances which they produce would lead too far into a technical field. Plant physiology and plant chemistry are subjects which are developing rapidly and which offer large opportunities for study. Here will be solved some of the most interesting and most difficult problems of life.

Chapter 9

THE PLAINS IN SPRINGTIME AND AUTUMN

All who find joy in the world of nature must have great delight in the plants of springtime. In Colorado, winter's brown passes very slowly with the oncoming of spring and, as elsewhere, the "oldest inhabitant" is wont to say that "we are having unusual weather; in the old days spring was always earlier".

One who knows only the climate of New England or the Middle Atlantic states finds it hard to realize the conditions that exist in Colorado. It is warm enough through the winter for grasses to be green but those of the previous summer are all dead and brown. Herbage is killed by the dryness of autumn and winter, and there is scarcely a bit of green anywhere. Warm weather often comes in February and early March but this does not bring green grass. There is no moisture to start growth. With the spring rains or snows of late March or early April there is a sudden bursting forth of greenness from the soil, just as if the grass had been down below the surface all ready to push through at the proper signal.

Then comes the early spring flora. Many flowering herbs brighten the landscape. On the plains the buffalo grass, grama grass, and bunch grasses with their tufts of light green make a restful ground tone into which is woven a charming pattern by the multicolored flowers which now appear.

There is something fascinating in the young outcroppings of grass and flowering herbs. It is delightful study, the attempt to name these different plants as they first appear. One may know them after they are well along, even before flowering, but to tell them apart when barely out of the ground is quite another thing.

Before the spring rains, if one gets upon some point of vantage and looks out over the plain, the first beginnings of green are seen along moist roadways or at the sides of irrigation ditches. Seepage areas flanking a roadside may be green all winter long. It is dryness then and not cold, for the most part, which keeps the grasses dead in winter. If one wished to pick out the spots where seepage occurs through a given area, winter or early spring

would be the time to do it. Later, the vegetation of these places is not so different in color from that of the ordinary dry country.

Among trees, willows are first of all to show color in spring time. Nearly all Colorado willows are small trees or shrubs but they look large because of the flatness of the country, being often seen across an open plain with few obstructions in the way. A ditch or shallow stream may be detected at great distance by the presence of willows or cottonwoods which fringe it, these sometimes extending in single file for miles on both sides at the water's edge but unable to spread farther from the bank because of dryness of the soil.

The yellow catkins of staminate flowers and the green pistillate catkins of the willow, give color to the individual trees at blossom-time before the leaves appear. It is possible to recognize even a half mile away from a ditch, those trees along the bank which are staminate and those that are pistillate. But this is only for a short time,—as soon as the leaves come out their wealth of fresh green color masks the special color of the catkins.

Geography of the Plains

The plains are sometimes thought of as flat expanses, dull and devoid of interest. Flat they are in places, but never uninteresting to one who studies their geology or the plants which they support. But even the typical "high plains" have considerable slope to the east, as is realized when it is remembered that Kansas City, is lower, by 4,000 feet, than Denver. Over much of the Great Plains region there are well-drained, gently-sloping areas alternating with shallow stream valleys or abrupt gulches cut by the rush of waters from many a storm. There is not that rolling character of the land which is to be noted in the Northeastern States, and which is the result of the deposit of glacial drift. It is clear that the great plains are of an entirely different geological origin. Indeed, their fine-grained soil is the deposit of silt from ancient rivers, which emptied at certain periods into the shallow sea which once existed to the east of the foothills and in other geologic times emptied into lakes of fresh or of brackish water. But long ages have passed since these various deposits were first laid down, and the storm waters from thunder showers, as well as spring freshets of mountain streams,

have worn away the land unevenly into various high plateaus, sloping valleys, and steep-walled gulches. In places where the soil is light, the winter winds of the centuries have been blowing dust and sand, building up mounds, carving out depressions, or spreading irregular drifts which, in turn, may be variously worn down again by water, or modified by the ever-recurring wind.

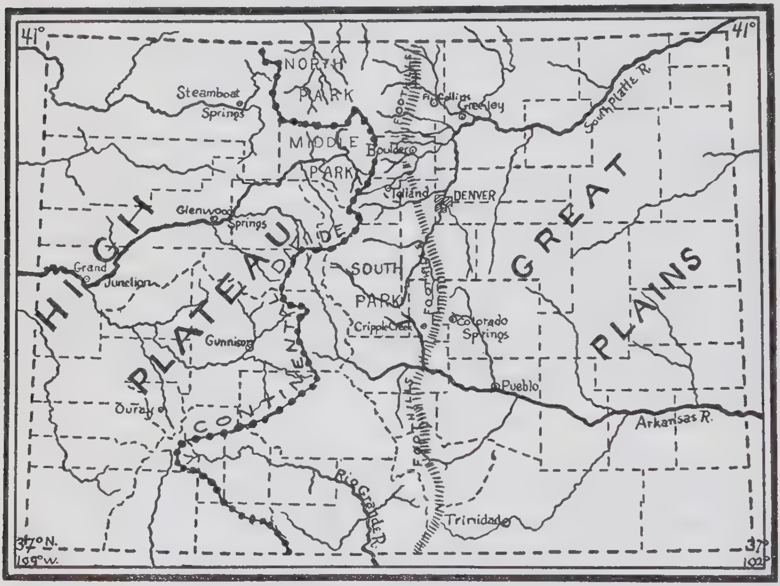


FIG. 60. Sketch Map of Colorado. The Great Plains lie to the east of the Rocky Mountains. West of the Continental Divide is a high plateau variously cut up into hills and mesas with intervening valleys. There is no growth of true short grass, but a great amount of sagebrush, in this high plateau region.

SHORT GRASS

Plateaus of wide extent still remain in places, little changed by Nature's forces—it is they that form the typical "plains". Here the short-grass occurs in characteristic form, just as it probably did in the days of the "pony express" or even of the Spanish explorer Coronado. Sometimes it has been held that the vegetation of the plains has changed greatly since the coming of the white man with his herds of cattle, that grazing kills off the taller grasses and favors a growth of buffalo grass and grama. Early residents of Nebraska, Colorado, and Wyoming seem not to agree with this view. They state that upland areas of fine-grained soil have always had, so far as their memory extends, a

cover of short grasses. Yet it is quite possible that certain lower and moister grounds which now have only short grass, did actually support a more luxuriant vegetation in former times. It must be remembered, however, that the grazing of buffalo and antelope went on regularly before domestic cattle were introduced.

It is likely that the layer of "hard pan" which exists about two feet below the ground surface in much of the dry plains country is of some importance in limiting the growth of taller grasses, since these are usually deep-rooted. The hard pan is not easily penetrated by roots except in wet seasons.

Some of the creek and river beds in southern Colorado have become wider and deeper since the introduction of domestic cattle. In dry seasons especially, the animals eat the shrubs and grasses along the streambanks. The denudation of the banks then permits greater erosion, with consequent widening of the stream bed. As a result of this "stream trenching", the water courses which formerly overflowed at intervals, become able to hold even the high waters of flood periods. So the flat or low-lying ground which, in earlier times, was inundated each spring no longer receives this irrigation. There has been the consequent change to more xerophytic vegetation,—short grasses where formerly there were tall grasses. In the northern part of the State, stream trenching is probably not of great consequence.

The Yucca, or Soapweed

A few only of the plains plants are evergreen; most are a dull brown in winter. The yucca (Spanish bayonet, soapweed) is green, and on that account it stands out as a prominent feature of the winter vegetation. (Fig. 15.) Most yuccas are a foot or two high, with stiff, sharp-pointed leaves; the plants look much the same at all times of the year. The common low-growing yucca of Colorado blooms in June, when a spike of large cream-colored flowers is developed. The flowers are, in general structure, much like those of Easter lily or tulip. Other kinds, especially those of warmer regions, grow to be small trees of grotesque form, and very handsome with a wealth of blossoms during their short period of bloom.

Most of the plains plants blossom in spring. This is because the wet weather comes at that time and the plants are

FIG. 61. Sand Lily. A white-flowered lily which grows in coarse soil of plains region and foothills.

stimulated to growth. The growing season is short on account of the dryness of summer and autumn. The sand lily which is so abundant in rough ground in early spring completes its growth before July, and the leaves die down and disappear. In the short period of the plant's activity an abundance of food material accumulates in the roots; some of this is used by the flowers of next season.

Sand Lily and Spring Beauty

Sand lilies are of great interest because they come up so early, and often in such unpromising soil. The leaves are a pale green, like the leaves of most dry-country plants, and there is no stem above ground. So the sand lily does not readily lend itself to house decoration, but it is beautiful when growing out of doors. Each flower is about two inches long, and often a great many flowers grow on a single plant. As the name implies, this plant belongs to the lily family and the flower is of the usual lily type, only much narrowed. Most people say that the flower looks more like a narcissus than like a real lily but the botanist objects to such a statement. He notices at once that the ovary, or seed vessel, of the sand lily is within the tube of the flower, not below it as in the case with the narcissus. The structures of flower and fruit are considered of more importance in telling the relationships of plants than is any general appearance of color or size in the flower or in the plant as a whole. (Fig. 61.)

The spring beauty is one of the earliest wild flowers. It has much the same appearance as its relative in the Eastern States. It is only when we have specimens of both plants together that it is easy to see the difference. Sometimes the flowers may be found as early as February, growing in moist soil among rocks in that part of the plains country close to the foothills, or in the foothills themselves. The petals are pink, with deeper-tinted veining. Like the sand lily, this plant has only a short growing season. Food which has accumulated in the underground parts is drawn upon, early each spring, to furnish material for the developing flowers. The spring beauty is a delicate plant, with small but thick leaves. The juicy, or succulent, leaves help to keep the plant from drying up; such leaves are often seen among plants of arid regions. (Fig. 62.)

MANY FLOWERING HERBS OF SPRINGTIME

It would be no easy task to describe all of the interesting spring-time plants of the plains; only a few can be considered. Besides the sand lily and spring beauty, there are the vari-colored loco-weeds or milk vetches, and the handsome yellow-flowered

FIG. 62. Spring Beauty. A succulent plant with thick leaves and large tuberous underground portion. The flowers are pink. Spring beauties bloom early in coarse soil of foothills and adjacent plains. Other species occur at higher altitudes.

golden pea, considered more fully in another place. Prickly-pears and other cactuses take on a brighter green color in the spring, and their handsome flowers, some yellow, some red, become conspicuous in June because of their abundance. Other plants of the plains so well known as to need little comment are the large bush morning-glories of sandy soil, the blue flag or iris,

of swampy places, and the purple-flowered thistle, the last named especially common in the southern part of the State.

Low, almost stemless, evening-primroses with large flowers nearly two inches across, form a striking feature of the landscape in places. They occur as great patches of white, acres in extent. They rival the daisy fields of the Eastern States for size and attractiveness. Evening-primroses are sure to impress the observer with the prodigality of nature. These flowers, so close to the ground, are very different in appearance from the erect-stemmed yellow-flowered evening-primroses so well known in most parts of the United States, but a botanist sees their relationship at once in the form of the flowers. (Fig. 16.)

SAGEBRUSH AND OTHER PLANTS OF DULL GRAY

In considering the plants of the plains, it will not do to omit the sagebrush. This so-called "sage" is not the same as the sage which housewives use to flavor the dressing of a Thanksgiving turkey. There is something of the same odor and a little of the same whitish-green appearance. But true sage is one of the mints, and has the usual square stem and opposite leaves of plants belonging to that family; the sagebrush of Colorado is one of the Composites and is related to goldenrods, asters, and thistles. Many kinds of sagebrush are only a few inches tall. The species now under consideration has, however, a distinctly bushy form and grows about three feet high. The whitish-green color of the plants gives impress to the landscape. Some prosaic people do not like it; they say it imparts an air of barrenness and desolation to the view. Something of the artistic temper seems needed for one to see the beauty of this gray-green. There is not the vividness which means fulness of life,—such greenness belongs to the grasses of early spring,—but there is a charm in the delicately colored landscape of midsummer with its softness of sagebrush and of other plants which reach their growth with the passing of the gayer spring season.

VEGETATION AND THE MARCH OF THE SEASONS

Springtime on the plains is a period of green grass and beautiful flowers. Crowded into the short season, come in quick succession dozens of different kinds of flowering herbs. Each day one may find some new plant starting above ground,

FIG. 63. Buffalo Grass (staminate plant). Buffalo grass is a typical short grass of the plains region.

soon to put forth a wealth of flowers that will help clothe the naked plain with a coat of many colors. But the colors soon fade, and with midsummer's heat comes a bluish gray, and the green grasses turn to brown and gold.

While the spring has ever been the favorite time of the poet, and the summer season has appealed most to the vacationist, yet there are many who find beauty, and interest as well, in the dying year. In colder parts of the world the thought of coming winter shadows the autumn landscape, and the chill rain and sighing wind seem necessary accompaniments of the falling leaves. Even the goldenrod and aster of late summer bring a touch of sadness, for soon will come the long period of frost and cold. In Colorado the climates are so varied that autumn may suggest very different things in different parts of the State. At Cripple Creek or Leadville or other high situations a long cold winter may be expected. In Denver, Boulder, Colorado Springs, and Pueblo the winter is bright, sunny, and dry except for occasional light snows.

The plants of autumn in Colorado are not very different from those of most of the United States. Goldenrods and asters are abundant both on the plains and in the mountains. It will surprise some who may think that a "goldenrod is just a goldenrod" to learn that there are twenty-three different species in the State, and as for asters there are no less than sixty-six. Naturally, the amateur botanist can not expect to tell them apart but he finds it of interest to know that this wealth of life exists, and to appreciate that so many different kinds of plants may bloom close to the end of the growing period.

Besides goldenrods and asters probably the gentians are best known and most admired of late-blooming flowers. There are the closed gentians, the fringed gentians, and the very handsome blue tulip gentian, or eustoma. (Fig. 85.) All are mesophytic and so are necessarily absent from much of Colorado, which is chiefly an arid area. About sixteen species of true gentians are known in the State, besides other plants of the gentian family, such as the swertia and the deer's tongue which would not commonly be called gentians at all.

Autumn in Colorado does not bring to ripening any great number of nuts or of attractive wild fruits. A few hazel nuts there are in fine-grained loamy soil along the smaller streams as these emerge from the foothills, but no walnuts or butternuts or hickories. Wild plums may occur sparingly, and choke-cherries sometimes in abundance. Ornamental berries are represented

by the blue fruit of the wild grape and Virginia creeper, the bright red kinnikinik and the brownish-red sumac.

FIG. 64. Buffalo Grass (pistillate plant). The staminate and pistillate plants occur together.

AUTUMN COLORS

At this point the author will have to ask indulgence while he wanders away for a moment from the plains to the foothills, for it is there that autumn color is best seen. Perhaps these few lines may induce the reader to take a trip to the canyons when

the leaves begin to turn and the less conspicuous green of summer gives way to the orange and red of autumn. If one expects to find whole mountain-sides aglow with crimson or yellow, one will be disappointed. There are no forests of red oak and maple and birch in Colorado. Yet, there are a few trees besides the somber evergreens. The scattered tree-shrub mountain maple becomes yellow and red, the quaking aspen a beautiful golden, and the cottonwoods show splashes of yellow where whole branches have assumed the autumn tint. Other native trees are not conspicuous.

While trees are few, there are many shrubs which assume brilliant colors. The sumac in Colorado, as elsewhere, early turns to a crimson red; the poison ivy and the three-leaved sumac which are near relatives assume different tints of gold and copper. Oregon-grape, which is really a kind of barberry, becomes tinged with cardinal.

In cities where shade trees from other localities have been set out, the trees behave just as in their native homes. The sugar maple and oak, which give so much color to New England forests, are seldom planted in Colorado, so that these particular sources of autumnal tints are lacking but the common soft or silver maple is much used for shade, and in the autumn it turns yellow and red, as elsewhere. Yet one who is familiar with the sugar maple notices that the soft maple gives but a very poor imitation of the other species' brilliant foliage. The red of Virginia creeper is as bright in river-bottom forests of Colorado as anywhere, and the yellow of wild grape leaves is clear and beautiful.

Not only may trees and vines assume the tints of autumn, but also the smaller plants. Three-top grass and other grasses become orange, and so do certain sedges and other common plants of the plains. The leaves of dwarf wild roses in the mountains assume brilliant shades of red, and the plants become fully as handsome as they were in summer when pink with blossoms.

While, in general, we can say which colors are assumed in autumn by certain trees or shrubs, yet there are times when plants behave in a very different way from the usual. Thus the aspens take on an autumnal yellow, and few people have seen them otherwise at this season. Yet now and then individual

trees and small groves become orange or red. Doubtless, careful observation would show like peculiarities among other trees. It would be worth while for some botanist to make a study of

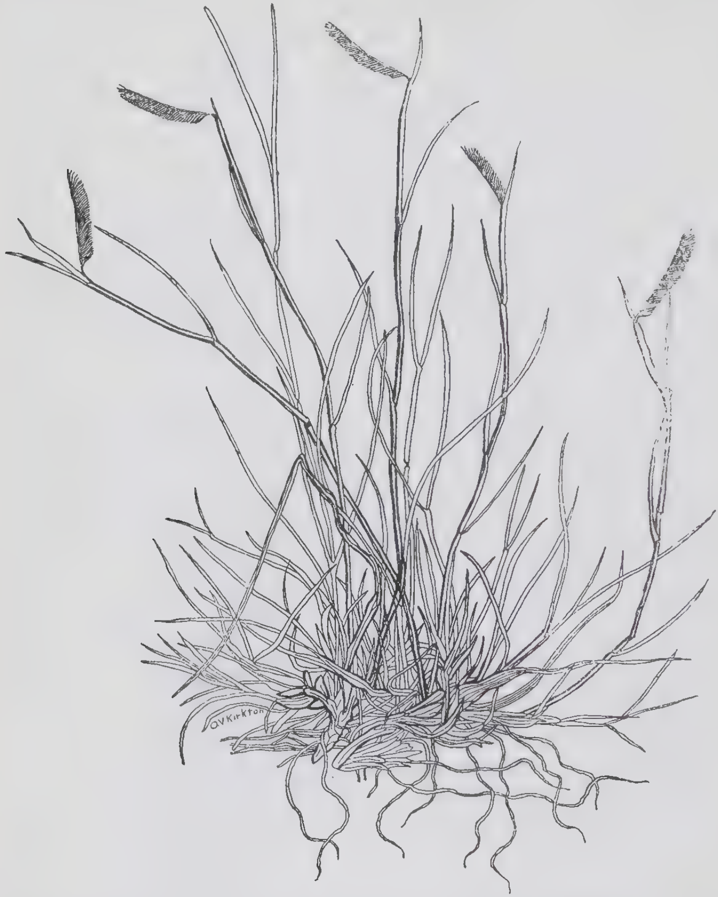


FIG. 65. Grama Grass. A short grass often associated with buffalo grass. It extends into the mountains beyond the range of buffalo grass. Grama grass is able to grow in somewhat coarser soil.

this peculiarity of aspens and attempt to discover what conditions bring about this unusual color of the autumn leaves.

The forests of the Eastern United States are world-famous for their autumn tints. Nothing like their brilliancy and variety of color is to be found anywhere in Europe. Japan, too, has

bright colors in autumn. Maple leaves turned red are considered by the Japanese to be quite as beautiful as ornamental flowers of iris or lotus. It happens that in the Rocky Mountains most of the trees are evergreens with needle leaves, and so there is not the same opportunity for bright colors. In Europe the species of forest trees are few in number as compared with those of the eastern United States, and the particular species that are found there happen to be ones which do not make a brilliant show in autumn. If, however, American or Japanese maples be planted in Europe they behave as they do at home. It is thus apparent that the lack of handsome autumn tints, whether in Europe or in the Rocky Mountains, is due not so much to peculiarities of soil and climate as to the absence of those kinds of trees which furnish color to the autumn landscape of New England or Japan.

Soil Quality Determines where Grasses may Grow

The different species of plants of the plains are not placed in hit-or-miss fashion but occur in certain relation to the soil and to other plants. Plants grow in particular places because in those places their physical requirements are met, or because of lack of competition.

The bunch grasses of the plains are deep-rooted and they produce their flowers and seed in late summer; hence they can grow only in soil which is deep, and into which the rains penetrate to some distance. Moderately loose and deep soil, especially if sandy, will furnish the necessary condition. Where such soil exists on the plains, the bunch grasses are likely to be found. In soil which is harder, sagebrush is more common than bunch grass. In shallow compact soil of somewhat loamy nature, the more densely-growing grama and buffalo grass become established and bunch grasses and sagebrush are kept out.

Ecological Succession

In the shifting soil of "blow outs", or crater-like depressions of the sandhill country in eastern Colorado a certain grass, *Redfieldia*, finds a place. Its branching underground parts weave a fibrous network which binds the shifting sands and thus stabilizes the soil. Soon other plants which could not live in unstable soil

get started and flourish; then the redfieldia becomes crowded out by the competition of these other plants. In this little drama of plant life the ecological principle of succession is well illustrated. Bunch grasses succeed redfieldia, then, in time, the bunch-grass vegetation passes over into a mixed growth of grasses and flowering herbs. On sloping well-drained ground, this mixed grassland

Fig. 66. Rattlesnake Grass (at left). Found in parts of the plains and foothill areas which have been over-grazed, or formerly cultivated and now somewhat grown up to weeds. This plant belongs to the genus Bromus which includes a number of large-flowered grasses.

Fig. 67. Sand Plantain (at right). Common in grassland of the plains region. The whole plant is gray-green. The small flowers are inconspicuous.

may persist for a very long time. In places where wind or water action bring in quantities of fine-grained soil material to cover the surface, true short grass may eventually develop.

Vegetation is nearly always in a state of change. Ponds and swamps dry up or are filled up by plant growth, giving rise to

conditions suitable for plants quite different from the aquatic and marsh plants originally present. Bare rock becomes softened, gravel becomes disintegrated, coarse soil becomes finer through the action of the elements; sterile ground is enriched by plant remains and becomes more capable of holding water. So it results that dry and barren soil changes in time to a soil which will support mesophytic species. Thus, whether our study begins with the vegetation of ponds or with the vegetation of rocky ridges it ends at the same place; in the plains region, a fine soil with some accumulation of vegetable remains (humus) always supports either a mixed grassland or else true short-grass vegetation. Districts with greater rainfall tend to have the taller grasses, but drier parts have short grass.

Plains Grassland; Climax Vegetation

Short grass may be said to form the ultimate or climax vegetation of large areas of the Great Plains; if broken up by the plow, or destroyed by the wheels of wagons or automobiles, it will appear again when the ground is left undisturbed for a long enough period. Short grasses are wonderfully well adapted to the conditions present in much of the great-plains country; the roots are shallow and widely spread so that they absorb the water of light showers which penetrate only a little way into the soil, the plants transpire little water, they spread rapidly, and they have a short growing season.

But even the short-grass cover is not a permanent one, because physiographic changes are constantly in progress. Every rain washes the gullies deeper and makes them head back farther into the level country. Strong winds may blow away soil, and root out the vegetation in one place, depositing dust somewhere else. Grazing animals injure and destroy vegetation, man tears up the land for roads or fields, permitting the entrance of weeds. But in spite of all disturbing factors, there is the inevitable tendency of the plains to become grass-covered. Climate, soil, and geographic position conspire to this end. There can be no doubt that much of the Great Plains area has been, for a long period of time, essentially as it is today. In contrast to this, it is interesting to note that flat areas in western Colorado do not develop a grassland but, instead, a growth of sagebrush, with a mere

sprinkling of grasses and flowering herbs in the interspaces between bushes.

OTHER PLANT COMMUNITIES

Certain land forms of the plains region support relatively permanent plant communities which are not dry grassland. Rock ridges and stream bluffs have a scattered pine forest, or in southern Colorado and on the Western Slope a mixture of pinyon pine and cedar. Water courses are flanked by fringes of cottonwoods; lowland seepage areas support a wet meadow or a willow thicket. Just as soon, however, as some portion of a stream bluff in the plains region develops the right kind of soil, this becomes occupied by grasses; the same thing happens with creek banks or seepage areas. Of course, a whole river bluff does not become worn down to fine soil all at once, nor do streamside forests become too dry for cottonwoods over extended stretches. So these less extensive plant communities, although not the ultimate vegetation of the region, may exist and, no doubt, have existed, for thousands or tens of thousands of years.

It will be of some value to make a list at this point of the principal plant associations of the plains region in Colorado. A knowledge of the several plant communities is not necessary for an understanding of the rest of this book but it is hoped that many readers will be interested. The list may be compared with the lists given later of plant associations in the foothills and mountains.

PLANT COMMUNITIES OF THE PLAINS REGION EAST OF THE MOUNTAIN BORDER

FOREST ASSOCIATIONS

Rock Pine Association:

Developed on dry river bluffs or in other stations where place rock is exposed. The common rock pine and cedar of the foothills are the characteristic trees, but hackberry, sand cherry, and various xerophytic shrubs are present.

Cottonwood-Willow Association:

The usual open forest of river bottoms; chiefly broad-leaf cottonwoods and arboreal species of willow, with some box-elders and lanceleaf cottonwoods. A growth of shrubs, especially dwarf willows, is found between and under the trees.

THICKET AND SCRUB ASSOCIATIONS

Willow Thicket Association:

Ecologically this is closely related to meadow for it is really meadow with an intrusion of scattered shrubby plants of narrowleaf willow. Chiefly in draws or low areas among sand hills.

Mesophytic Mixed Thicket-scrub Associations:

In moist situations within small gullies. The chief woody plants are choke-cherry, plum, buck-brush, mountain maple, rose, poison ivy. Various consociations are recognizable, characterized by the abundant presence of one or another of the species named.

Xerophytic Mixed Shrub Associations:

On dry bluffs, exposed rock, and the slopes of open gullies. Common shrubs are the three-leaved sumac, mountain mahogany, and currants.

Sagebrush Association:

The thread-leaved sage, or sand sage, dominates wide areas of sandy soil, constituting a plant community which is ecologically related to the bunch-grass association.

Rabbit-brush-Atriplex Association:

In deep soil, either sand or fine-grained shale that is easily penetrated by the large roots. The plants are fully as xerophytic as sagebrush.

HERB ASSOCIATIONS (GRASSLAND)

Lichen Association:

On exposed rocks and coarse soil. The lichens are of rather few species.

Redfieldia Association:

A growth of the grass redfieldia, in wind-eroded crater-like depressions known as "blow-outs," found in the sand hills of eastern Colorado. Redfieldia acts as a sand binder, thus stabilizing the soil and permitting the growth of other plants. This association is often the forerunner of bunch grass.

Inceptive Grassland Association:

In compacted shale or other sterile soil. Different stages of development may be recognized, starting with the mat-forming plants of ridges and moving toward some one of the more definitive grassland types. Two composites, *Gutierrezia sarothrae* and *Artemisia frigida*, often occur in abundance, forming a Gutierrezia-Artemisia society.

Sandhills Mixed Association:

A miscellaneous aggregation of plants able to exist in loose, sandy soil. Various grasses occur, especially wheat grass and some of the bunch grasses. The thread-leaved sagebrush is common, the Rocky Mountain bee plant, and many other plants of primitive communities. Numerous minor communities are recognizable; one of these is the Porcupine-grass (Stipa) consociation. This is of such wide-spread occurrence and reaches such relative permanence that it may deserve the rank of an association. If so considered, it would be listed between the Wire-grass and Short-grass associations.

Bunch-grass Association:

An open growth; chiefly bunch-forming grasses and scattered flowering herbs, in soil of hill crests and slopes. There are many different consociations and societies dominated by different characteristic plants. Newer growths are often quite different in floristic composition from the areas which are better established, the latter tending toward the short-grass vegetation type. The most distinctive grasses, although not always present, are Andropogon and Sorghastrum, late-flowering species which grow only where there is a moderate supply of moisture lasting through the summer.

Wire-grass Association:

Somewhat less xerophytic than the inceptive grassland, and in finer-grained soil. Wire grass (Aristida) and Porcupine grass (Stipa) are characteristic. Grama grass, when abundant, points to a coming change of the area to short-grass vegetation.

Short-grass Association:

Widely developed in the plains region. The characteristic plants are buffalo grass and grama grass. Buffalo grass occurs in dense growths only on fine-grained soil, while grama grass occurs also upon coarser material. Each may form by itself a definite consociation in which the other is nearly or entirely absent. The short grasses may make a dense ground-covering of almost pure stand where soil conditions are favorable. More often, however, there are scattered grasses, cactuses, vetches, composites, and other plants.

Wheat-grass Association:

Dominated by western wheat grass. In fine-grained soil of good quality and not so hard and dry as that of the inceptive grassland. Developed chiefly within a few miles just to the east of the foothills.

Meadow Association:

Mesophytic grassland along streams, at the foot of slopes, or in other favorable situations. Blue grass, June grass, and other grasses especially common. Moister parts of this grassland are often invaded by clover, timothy, squirrel-tail grass (wild barley), and dandelions. Clearly marked consociations and societies are numerous. Occasionally some cottonwood trees are present, and willows are sometimes so abundant as to change the meadow into a thicket or scrub community.

Weed Associations:

Abandoned fields, over-grazed pasture, dooryards, and roadsides have a weed flora which varies with the moisture, with the nature of the soil, and with opportunities for seeding. Native annuals are usually the first plants to enter ground open to invasion but weeds from the Eastern United States and from Europe are also important. These various plants have such different growth forms that a number of different weed associations should, no doubt, be recognized.

Pondweed Association:

In shallow water here as elsewhere in the United States. Various species of pondweed (Potamogeton) and other submersed plants occur. Occasionally an abundance of stonewort (Chara) gives rise to a Stonewort Society of the Pondweed Association.

Pondscum Association:

In quiet water, often among cat-tails and bulrushes. There are species of true pondscum and other algae.

Duckweed Association:

Made up of duckweeds and starwort. Small floating plants of quiet water.

Bulrush-Cat-tail Association:

At edges of lakes, in wet parts of marshes, and in wet draws. This is much the same kind of growth as is seen in like situations in the eastern United States and indeed also in Europe and Asia.

Sedge-Rush Association:

This belongs to low ground with poor drainage. It occurs in many places in sand-hill country of eastern Colorado. Besides sedges of the genus Carex there are the spikerushes (Eleocharis) and the true rushes (Juncus) with a miscellaneous collection of marsh grasses and other plants of wet areas. Modifications in floral composition lead to the development of various locally prominent consociations and societies within this association. Among these, are a Smartweed Society and a Water-plantain Society.

Alkali-land Associations:

These form a sparse vegetation cover in fine-grained, generally clay, soil. Certain grasses are usually present, but more conspicuous than these are various coarse weeds of the Goosefoot Family.

Chapter 10

MESAS AND FOOTHILLS

Many dwellers of the eastern and central United States have not heard the word "mesa" and yet to those who live in the Rocky Mountains it is a most familiar term. A mesa is a flat-topped hill or ridge, a table land, usually of no great height, sloping away from the foothills. As a rule, the top of the mesa represents a former general land-level and the mesa then is a remnant. The land around it has been washed away, or eroded, by the action of water through centuries of rain and stream-flow.

The mesas occupy, as a rule, a definite position below the foothills, from which they project out to the plains some hundred feet, or even a few miles. Sometimes the mesa has no apparent connection with the foothills at all, having been isolated by the headward cutting of small lateral streams. In such cases, especially if worn away at the top, it comes to look like an ordinary hill. If it have steep sides it is likely to be called a "butte". Much of western Colorado is "mesa country", where an intricate network of water-courses has isolated mesas of all shapes and sizes, some of very great extent.

Features of Mesa Vegetation

Since the mesas are higher than the general level of the plains and lower than the true foothills, they form a meeting place for the plants of the two regions. Frequently there are alternating patches of vegetation in which, now the mountain species, and now those of the plains, predominate.

It must not be supposed that the plants of mountain and plain are entirely different. Indeed, many plains plants extend well into the foothills. They may pass up along dry slopes, some a short distance only, some to an altitude of 1,000 or even 2,000 feet above the level of the plains. Typical examples are the scarlet mallow and the sand lily. But such plants will not usually be found on north slopes nor on moist canyon walls. Then again, certain mountain species extend far into the plains country but they are chiefly such as grow along water courses. Mountain maple is a good example. Individual trees or small clumps of this maple are found scattered from the foothills even into Kansas and Nebraska—but always along streams.

Fig. 68. Winter Scene on a Mesa, looking toward the foothills. The rock pines in the picture show the lower timber limit. The shrubs in the foreground are sumac.

Fig. 69. Buttes in Northeastern Colorado. On these buttes there is a small colony of the limber pine, a tree ordinarily found only in the mountains above 7,000 feet altitude.

It might be asked why the plains species do not grow on the moister slopes of the foothills and thus cover the entire foothill region. Is it too wet for them there? No, it is not too wet but the locality is already occupied by other plants. Almost all kinds of plants would do well enough in this moister soil, but there are those which belong to this particular habitat and they hold possession. The plants of the plains are suited to dry conditions; so they thrive on the plains. If the flora of some isolated mesa should all be destroyed, the plants of the adjacent plains would, no doubt, soon occupy their places. They would continue to exist there for a long time, until gradually replaced by plants the seeds of which would come in from hills at a distance.

SOIL DIFFERENCES; THEIR INFLUENCE ON VEGETATION

Certain differences exist between the soils of plains and those of mesas and foothills. The former are made up of fine-grained material and are moderately soft above but hard and compact at no great depth; mesas have a certain amount of coarse broken rock and gravel, and the foothills are of solid rock or rock fragments with a surface soil of disintegrated sandstone or granite. In the plains country at Denver and in many other localities, there are no stones; almost the only pure sand or gravel to be found is that along stream beds.

Differences in soil are important in limiting the plains plants to the plains and the mesa plants to the mesas. These differences are partly responsible for the presence of trees on the mesas and absence of trees on the plains. The plains, with their fine-grained soil of little depth, are well suited to the spreading and shallow roots of many grasses, but are not adapted to the growth of pines which, in Colorado, are invariably found in stony or gravelly places. It must be said, however, that pines are able to grow in fine soil if this is sufficiently sandy, and actually do so in New Jersey and Michigan and also in various places in the Southern States.

The importance of soil differences in determining tree distribution is well shown in Middle Park, at Sulphur Springs. At an altitude above 7,000 feet, surrounded by timbered foothills, there are grass plains and sagebrush flats. Surely at this high altitude it is cool enough for pines, but the soil of the valley is of a kind

which bakes hard and is very fine-grained. It would be difficult for the seeds of pines to sprout and get started. Young seedling pines do, however, spring up along abandoned roads or in railway cuts where the soil has been loosened and the original grass vegetation has been destroyed.

The lower limit of trees on foothills and mesas is often sharply drawn. In fact, a lower "timberline" may look as if made by cutting down of trees below it. Above are rock pines, becoming more dense and making a closer forest high up on the mesa, while below is the prairie grassland with no pine trees at all. This line of division is determined chiefly by soil conditions, partly by the factors of temperature and rainfall.

FIG. 70. Pasque Flower (at left). Flowers are lavender, appearing in very early spring.

FIG. 71. Pasque Flower, in fruit (middle). The styles have grown out into long tails extending from the seed-like fruits. (These drawings of pasque flowers are about one-half natural size.)

FIG. 72. Rock Primrose, or Androsace (at right). A plant of moist slopes in the foothills or on mesas. Other species of the same genus are found in the higher mountains and even above timberline.

RAINFALL, CLOUDS, HUMIDITY, TEMPERATURE

Mesas and foothills have a slightly greater rainfall than have the plains. This is seen in summer time when there are afternoon showers in the hills but no precipitation at lower levels. In winter, many a light snow in the mountains does not extend down below the foothills. Such increased precipitation, little as it may be, makes conditions for tree growth better than on the plains. In early spring there are days at a time when clouds hang down on hills and mesas keeping the air moist, although the plains are dry.

But it is not only in the coarse-grained soil and in the slightly greater rainfall and humidity that mesas differ from the plains.

Temperature is a factor of importance. Studies made by the writer show that, in the spring, night temperatures on the mesas are not so low, nor the day temperatures so high, as on the plains. The mesas have the less severe climate.

In March and early April there is often very warm weather on the plains, followed by a cold season of continued frosts and snow. Trees that have been planted on the plains are very likely to come into flower or leaf at this time of warm weather. Then, with late spring frosts and cold, they may be killed back. If pine seedlings were to get started on the plains they too might be killed by frost following the early warm weather of March. It is the experience of gardeners and fruit-growers that the lower edges of foothills or mesas are best for their ranches. It is known to nurserymen that many ornamental shrubs and vines are hardy in the cities at the bases of the foothills, although they winter-kill if planted at Denver or other points a few miles out on the plains.

Soil temperature is an important factor of plant distribution on the mesas themselves. The north slopes and south slopes have different amounts of sunlight and shade. Temperature records taken in holes bored a foot or more deep show that the soil of south slopes warms up much earlier in the spring and stays warmer all summer than that of the north slopes. If the soil becomes warm early in the season it follows that trees begin to grow early. In this way they become subject to injury by frosts in late April or in May. South slopes of mesas often have very few trees, while the north slopes are likely to be well timbered; soil temperature is probably the chief determining factor. Dryness must also be considered, for the greater heat of the south slope will make the soil dry out more rapidly after each rain.

Trees of the Mesas

Rock pines and cedars are the trees of the mesas generally, but in southern Colorado and also west of the Continental Divide, pinyon pines and oaks, chiefly of small size, are also present. Pinyons and cedars tend to occupy warmer and drier soil than the rock pines; hence are usually lower down on the hills.

The Story of the Limber Pine

Some ridges have limber pines instead of rock pines. An example of this condition is found on certain bluffs west of Pawnee

Buttes in northestern Colorado, at an elevation of little over 5,000 feet. Elsewhere the limber pine grows in much higher altitudes, generally above 7,000 feet; and it often extends as high as 11,500 feet, where it occurs with sub-alpine fir and Engelmann

FIG. 73. Wild Onion (at left). This particular kind of onion has white flowers and grows in moist soil. Some onions have pink flowers. There are 13 native species in Colorado.

FIG. 74. Double Bladderpod (at right). A gray-green plant which produces an abundance of yellow flowers in early spring. The bladdery pods which follow the flowers are conspicuous.

spruce in the "wind timber" at timberline. Pawnee Buttes are seventy miles east of the foothills, with no intervening limber-pine country, although there are bluffs and ridges with cedars and occasional rock pines. An explanation of this strange occurrence of limber pine can be reached only by a consideration of the past

history of Colorado. During the glacial period in North America, the Rocky Mountains of Colorado were covered with ice over what are now the alpine and sub-alpine regions. In many places, glaciers extended down to an altitude of 9,000 feet or lower. The climate of the whole region was probably somewhat colder than now. It is likely that in those days limber pines grew down even into the lowest foothill districts, and also grew on ridges and bluffs perhaps far to the east. If this was the condition at that time it is evident that the little patch of limber pines now growing near Pawnee Buttes is but the remnant of what was continuous forest in the foothills, and which extended eastward in favorable situations many miles. The present geologic period with its warmer and drier climate made conditions suitable for limber pines up in the mountains. The few on the bluffs near Pawnee Buttes were able to survive, perhaps because of cooler soil or moister conditions than exist in the lowland points. This colony of trees probably has persisted and reproduced itself for thousands of years, removed many miles from any forest or grove of its own species. A similar colony of limber pines occurs in the Black Hills of South Dakota.

Why Pines Grow Among Rocks

One reason that pines do not grow naturally on fine-grained soil is that they can not get started there. There is no room in the soil for their roots because of the wealth of grass roots already present. Further than this, seedling pines need to be shaded, and there is no shade for them on the plains. Where large rocks abound, as on mesas or buttes and foothills, any seedlings which happen to spring up in the shelter of a rock are shaded for a few years and may thus become established.

The soil around a large rock is always more moist than elsewhere, because the water which runs off from the rock during rain does not get far away. Everyone knows how quickly the grass of a lawn grows up, after cutting, along cement walks; in nature, the same increased moisture is to be found at the edges of large boulders and scattered rocks. If the outlying pines on a mesa be examined, it will be found that each one has come up in the shelter of a rock which played the part of nurse to it in early life.

ROCK RIDGES

An interesting region of the foothills is the rock ridge country of northern Larimer County close to the Wyoming line. The surface of this area might be compared to a piece of corrugated iron except that the corrugations in this case are not perfectly

FIG. 75. Bergamot or Horsemint. A lavender-flowered mint which grows in clumps in somewhat moist areas of the lower foothills.

symmetrical. Sandstones and limestones of varying degrees of hardness form the material of the ridges, while the valleys are usually softer stone filled up with washings from the adjacent ridges. The direction of the ridges is north and south, following the general trend of the mountain front at this point.

As the ridges are constantly weathering away under the action of frost, they consist of coarse rock with very little good

soil. Any fine-grained soil is likely to be carried down by rains into the valleys. From time to time, the valleys are washed still more, by rains which transport this finer material into the streams that cut across the ridges and flow eastward to the plains.

Xerophytic Scrub

Mountain mahogany bushes cover the rock ridges of northern Colorado with an open scrubby growth, and there are a few scattered pines. Some of the strata in certain ridges are partly limestone and gypsum; on these the bushes are few and far between, probably because mountain mahogany requires a loose, well-aerated soil. A lower shrub-limit exists here corresponding to lower tree-limit on mesas. It is so sharply marked in some places that it looks as if the shrubs had been planted on the hillsides and grass planted in the valleys. Elsewhere, however, there are some groups of outliers, chiefly three-leaved sumac, which extend below into the grassy valleys.

The scrub growth of rock ridges and foothills is not always made up of mountain mahogany. Thus, at the mouth of Platte canyon, southwest of Denver, there are many other shrubs. Oaks are abundant, three or more species. Then there is the three-leaved sumac sometimes mixed in with mountain mahogany, but often in almost pure stands. Many outcrops of shale, not covered by good soil, have a growth of little but three-leaved sumac. It is possible to judge something of the geology by an examination of the growing plants, and it is easy to predict that certain geological outcrops seen at a distance will be found, on closer scrutiny, to bear vegetation made up of particular species of shrubs.

Scrub vegetation in Colorado, as in other western states, is often known as chaparral. Usually the term is employed for a moderately thick stand of shrubs of xerophytic or meso-xerophytic type. Chaparral has been characterized as "nature's unsuccessful attempt to make a forest". The oaks, especially, are chaparral-forming plants but there are also the mountain mahogany and three-leaved sumac already mentioned, besides thimbleberry, gooseberry, currant, rose, New Jersey tea, and others. Some ecologists prefer to limit the use of the term "chaparral" to a plant community chiefly of broad-leaved evergreen shrubs, as

the chaparral of the Coast Range in California. This limitation would require dropping the word "chaparral" in Colorado and substituting "scrub" or "shrub association".

The oaks of Colorado all grow in mesa and foothill country and, for the most part, on steep slopes and crests of ridges. The various oaks are difficult to distinguish; the species are variable as to leaf form, and they are not easily recognized even when typical specimens are compared. Ten or a dozen species are

FIG. 76. Wood Lily. A handsome red-flowered lily of wet meadows in the foothill zone. Now becoming very rare. It should not be picked.

known in Colorado; most of them are shrubs, only a few attain tree-like proportions. There are no black, red, or scarlet oaks such as are abundant in the Mississippi Valley States. Not one of the Colorado oaks extends into those states; they form definitely a Rocky Mountain group of plants.

VEGETATION EAST AND WEST OF THE CONTINENTAL DIVIDE

Contrasts of vegetation to the east and west of the Continental Divide deserve some consideration. A list of plants collected in Middle Park or in the western part of the State will

show rather few species unknown on the eastern slope, yet the relative abundance of different species is not the same. Furthermore, the total number of species is smaller. Buffalo grass and grama grass are absent in the west; there are no grassland areas of large extent. Some of these differences, as well as others, are indicated in the following account, adapted from a report by Dr. W. W. Robbins on the botany of northwestern Colorado:

> One who passes from the eastern to the western slope of the Rocky Mountains in Colorado cannot fail to be struck with the difference between the vegetation of the Great Plains and of level areas in the western part of the State. The plains of eastern Colorado are grass covered; level stretches of western Colorado bear a growth chiefly of sagebrush with only scattering grasses and flowering herbs.
>
> The sage (Artemisia tridentata) is most abundant on flat expanses back from streams; it occurs on flat areas generally, reaching its greatest development in deep, fine-grained soil. As slopes become steeper and more stony, with less soil, the sagebrush gives way to pinyon pine, cedar, and such shrubs as are typical of rocky ridges. On north slopes, sagebrush often grades into scrub oak. Rabbit-brush is a common associate of sagebrush, especially in moister areas near to creeks; greasewood alternates with sagebrush in alkaline soil.
>
> Oak thicket is common in northwestern Colorado, just as it is east of the Divide to the south of Denver. Oak at lower altitudes forms a transition between sage plain and rock ridge, often extending as a fringe along the bases of slopes. Intermixed with the oak are bushes of mountain mahogany.
>
> Southern plants extend farther north in western Colorado than they do east of the Divide. Examples are: oaks, joint-fir, pinyon pines, and Wislizeni's cottonwood. The climate of northwestern Colorado is drier from the vegetation standpoint than that of eastern Colorado at the same latitude and altitude; hence southern forms find, on the drier western slope, conditions more nearly like those to which they are accustomed in the arid districts of New Mexico and Arizona.—A Botanical Trip in Northwestern Colorado (1910).

THE PASQUE FLOWER

The pasque flower—or anemone, as it is often called in Colorado—is one of the earliest blooming plants of spring. (Fig. 70.) Since it never gets down on the plains, it must be considered a true foothill and mountain species. This plant grows in coarse soil, hence it should not be expected on the plains. Pasque flowers are so common and so much talked about in early spring that every visitor to Colorado should know something about them. When the flower-buds first come above ground in February or March they remind one of goslings, or perhaps of maltese kittens, because of their fluffy, gray coats. Later, as the buds open, the flowers are a welcome sign that spring has come. There are no leaves with the pasque flower when it blossoms, and many

people do not know that there are ever any leaves. The plant comes up as a single flower or a small cluster, directly from the under-ground stem which has within it sufficient nourishment

FIG. 77. Fire-weed (at left). The purple flowers of fire-weed are seen in forest openings of the upper foothills, montane, and sub-alpine zones. The plants grow to a height of two or three feet. They are especially common in burned-over areas.

FIG. 78. Coral-root Orchid (at right). This is a root-parasite. The plant is yellowish brown and flowers are not greatly different in color from the leaves and stems.

accumulated the year before, to furnish food for the development of the flowers. When the flowers are through with their work the leaves appear, and begin to make the food which will be needed for next season's blossoms.

In the pasque flower, only one set of floral leaves is present. These are the sepals, as botanists call them. Most people would think of them as petals because of their delicate texture and their pale blue or lavender color, but it is a rule of flower-description to use the term petal only when there are the two sets of floral leaves, in which case the outer are called sepals and the inner petals. In the pasque flower there are no outer and inner floral leaves, but just one set, so these are known as the sepals. In the center of the flower are the numerous pistils, surrounded by the still more numerous stamens. The pistils develop in ripening to long-tailed dry fruits much like those of the clematis, so well known as a climber on porch trellises and walls. Below the flower some distance is a circle of bracts forming the involucre. This is sometimes mistaken for a calyx but is not a part of the flower at all.

KINNIKINIK AND OREGON-GRAPE

Kinnikinik and Oregon-grape are also plants found chiefly on foothills and mesas. These species stop rather abruptly before reaching the plains although in places they extend out into the plains region, growing on bluffs or ridges. Both are trailing plants. (Figs. 1 and 3.)

The kinnikinik is well known to people of the Northeastern States under the name of bearberry. The bright scarlet fruits and small thick, dark-green leaves are highly ornamental. Besides, the delicate pink flowers which come in early spring are almost miniature counterfeits of the handsome trailing arbutus of New England.

Oregon-grape is a true western plant. The name is somewhat misleading, as it is not a grape at all but a kind of barberry. The leaflets of its compound leaves remind one at once of holly. They are dark green, shiny, and provided with sharp teeth. They live through the winter, so the plant is evergreen. The fruit of Oregon-grape is a dark-blue berry about the size of a common wild grape and if gathered in quantity may be used in making jelly.

PHLOX AND ITS RELATIVES

Phlox is a name well known because of its numerous cultivated garden forms which are so common. These cultivated types were originally wild, and they still grow in their native

homes. The annual phlox, a favorite old-fashioned flower, comes from Texas, and the large late-blooming perennial species grows wild in the states from West Virginia to Florida. The phloxes of Colorado are not tall plants; they grow close to the ground, some forming loose mats, others dense cushions. But they flower profusely, and rather early in the growing season. The prevailing flower colors of phloxes are white and pink; some tend toward purple and lavender. On dry rock ridges and buttes, really outward extensions of the foothills, there is a species of most typical cushion form which looks quite as much like an "alpine" plant as the phlox which really grows above timberline. Other species of phlox maintain themselves in the shrubless interspaces of sagebrush country.

The phlox family is one of the "higher" families of plants, as is evidenced by the corolla being all in one piece, not divided completely into separate petals. Besides the phlox, other members of the family in Colorado are the gilia and collomia. The pink gilia has long, narrow trumpet-shaped flowers. It is a summer-blooming plant of foothill country, especially common in southwestern Colorado. (Plate III.)

The Turret Plant, Deer's Tongue, or Green Gentian

The turret plant, or deer's tongue, is a member of the gentian family, but does not have the blue flowers which we usually expect to see in a gentian. It grows two or three feet tall, and the flower cluster is considerably branched. The large rather thick oblong leaves are of a grayish-green color and the petals of the flowers too are greenish. Turret plants grow in mixed grassland of foothills, both on the level ground and on slopes. They stand up so far above the surrounding low growths, and they are of such erect and symmetrical form that the name here used is very appropriate. At certain points they extend up almost to timberline.

The Mariposa Lily

No account of the foothills would be complete without some reference to the mariposa lily, one of the best-known of Colorado wild flowers. (Plate II.) The plant has a flower of the true lily type with a single pistil, six stamens, three petals, and three sepals. To look into this flower is to gaze into a cup of mystery,

to study it intently is to penetrate the very heart of nature. Mariposa lilies are of various species but the best known is the one with pale purplish petals, each of which bears inside a broad velvety darker-colored gland. Colorado does not have the modestly drooping forms of mariposa lily known in California but may well be content with the slender erect kinds which form such a beautiful feature of foothill meadow or grassy hillside. These much-admired plants should not be gathered, but should be allowed to display their loveliness in their own native habitat.

The Characteristic Plants of Foothill Country

In picking out the plants to be mentioned in this chapter only characteristic species have been selected. Interesting shrubs and handsome flowering herbs of numerous kinds grow on the mesas and foothills but many of these are to be found on the plains as well. Rock pines, cedars, pasque flowers, Oregon-grape, kinnikinik, phlox, pink or scarlet gilia, turret plant, and mariposa lily are not plains plants at all. Wherever these are found is foothill country.

Spring and early summer bring to mesas and foothills almost countless flowers of brilliant hue or pleasing form. At that time only is there much soil moisture, and so the flowers of many plants come all at once. With the arrival of summer there is less of color, but in early autumn, masses of yellow again appear as the butterweeds and other coarse composites come into bloom.

Plant Communities of Mesas and Foothills

The various plants of mesas and foothills grow together in communities which vary with soil, exposure, rainfall, and past history. Some of these are pioneer communities just becoming established on soil of recent origin. Most, however, are past the first inceptive stage and consist of plants which require at least a moderately fertile soil. A few communities represent the ultimate, or at least the penultimate type of plant growth for this particular region. These are made up of plants unable to exist in either coarse, dry, gravelly soils or in swamps or moors; they are either true mesophytes, or almost mesophytes.

An enumeration of the more common plant associations of mesas and foothills may be of value to the reader who enjoys the field study of plants. These associations are best classified as

of four types· forest, thicket, scrub, and grassland. An association may, in places, have a great abundance of one or two species. If these are among the usually important species of the association this part of the community is then called a "consociation" and given the name of the dominating species. If these locally-abundant plants belong to the usually less important species, the community is called a "society." The minor communities are not listed in the following synopsis which is an enumeration of the associations.

ASSOCIATIONS OF MESAS AND FOOTHILLS

Forest Associations

Pinyon-Cedar Association:

In hot, dry situations; especially in the southern and western parts of the State.

Rock Pine Association:

Usually an open forest on foothills and mesas but sometimes producing a close stand. When quite open it may be called a "coniferous savanna." This is the characteristic foothill forest of Colorado.

Douglas Fir Association:

In deep ravines and on north slopes; individual trees sometimes occur in exposed and dry places.

Lodgepole Pine Association:

Characteristic of the montane life zone but present on north slopes in the upper foothills.

Spruce Association:

The dominant species are the Colorado blue spruce and Engelmann Spruce, mixed or as separate consociations. Engelmann spruce belongs characteristically to moist situations in the montane and sub-alpine zones. The Colorado blue spruce is generally confined to valleys in the foothills.

Aspen Association:

Often a "second growth" after forest fires, producing a rather temporary forest to be displaced later by pines or Douglas fir. More frequent in the montane than in the foothill zone.

Cottonwood-Willow Association:

A fringing forest along streams; best developed in rather open parts of canyons and just below canyon mouths. Broadleaf, narrowleaf, and lanceleaf cottonwoods may be found together or in separate locations; the black willow grows to be a large tree.

Thicket Associations

Oak Thicket Association:

Made up of large shrubs with some small trees. A community of moderate, rather than extreme, xerophytism chiefly on fine-grained soil. In the southern and western parts of Colorado.

Thornapple-Plum-Cherry Thicket Association:

Chiefly near streams in alluvial soil; large shrubs and small trees.

Alder-Willow-Birch Thicket Association:

In wet humus soil close to streams. Often there are pure stands of alder or of willow, when the community could be called an Alder Consociation or Willow Consociation of the Alder-Willow-Birch Association.

SHRUB ASSOCIATIONS (SCRUB)

Xerophytic Mixed Shrub Association:

On rock ridges and hillslopes. This may consist of a few or many of the following: Three-leaved sumac, oak, currant, thimbleberry, New Jersey tea, mountain mahogany, kinnikinik, Purshia. Some of these form, in places, definite consociations or societies.

Ceanothus Association:

Patches of the low-growing spiny species of New Jersey tea (Ceanothus fendleri) grow upon dry or gravelly hillsides usually in areas of inceptive or mixed grassland.

Sagebrush Association:

The shrubby species of sagebrush with three-toothed leaves characterizes this xerophytic association of plants usually growing in deep fine-grained soil. Greasewood and rabbit-brush frequently grow with the sage or they may form well-marked consociations in which one or the other predominates and in which sagebrush plays a minor role.

Sumac Association:

This plant community is often a temporary one on soil which has been denuded by storm erosion or by operations of man. The characteristic plant is the ordinary mountain sumac, not the three-leaved sumac mentioned as a member of the Xerophytic Mixed Shrub Association.

Kinnikinik Association:

Kinnikinik (bearberry) forms creeping mats, usually a few square yards in extent scattered in areas of inceptive or mixed grassland but sometimes also on the floor of aspen groves.

Buckbrush Association:

Patches of buckbrush, (Symphoricarpos) a shrub about two feet tall, occur chiefly scattered in deep fertile soil of meadow grassland.

Mesophytic Mixed Shrub Association:

Made up of many species of shrubs, a few or many kinds occuring together. Common members of the association are rose, poison ivy, Oregon-grape, sumac, ninebark, raspberry, and gooseberry, with sometimes wild mock-orange in rock crevices.

Streambank Shrub Association:

A community of moist and fertile soil, the chief plants being hazel, dogwood, golden currant, gooseberries.

HERB ASSOCIATIONS (GRASSLAND)

Lichen Association:

A community of lichens growing on the rocks of canyon walls and upon exposed rocks and coarse soil elsewhere. There are certain true mosses of this habitat which belong ecologically to this association.

Inceptive Grassland Association:

This term may be used to describe the early stages in development of grassland on coarse dry soil of gravel slides, mesa tops, and exposed foothill stations. It begins with lichens, dwarf clubmoss, and cushion plants, then adds certain xerophytic sedges, grasses, and herbs of various types. There is usually a considerable amount of bare ground. A low species of mountain sage is often abundant.

Mixed Grassland Association:

A stage of vegetation developed from the inceptive grassland. The number of species has increased and the mat and cushion plants have disappeared or have become inconspicuous. Porcupine grass (Stipa) and June grass (Koeleria) are important. In this and in other grasslands, various consociations may be recognized in different areas, characterized by the abundant presence of one or another grass species. Two or more consociations or societies are recognizable in which different species of flowering herbs predominate.

Bunch-grass Association:

Chiefly confined, so far as mesas and foothills are concerned, to rather local wind-swept exposed rocky slopes.

Short-grass Association:

Characterized by grama grass and buffalo grass. On mesas and foothills the former is frequent and the latter seldom occurs except in small patches.

Wheat-grass Association:

A specialized grassland in deep soil of good quality; chiefly wheat grass with few flowering herbs. Wheat grass is common also on sand hills and sand dunes.

Roadside and Garden Weed Associations:

These vary with the soil, whether humus, sand, clay, or gravel. Some of the weeds in Colorado are derived from Europe and from the eastern United States but many are native, belonging commonly to pioneer plant communities.

Meadow Association:

Developed in moderately moist areas of fine-grained fertile soil. Among the more characteristic plants are blue-grass, blue larkspur, harebell, aster, yarrow, mountain daisy.

Sedge Association:

Chiefly made up of sedges (Carex) forming various consociations, as: (a) Half-submersed sedge growth of ponds, (b) Sedge swamp of tufted hummocks, (c) Sedge moor of wet soil but verging toward meadow.

Moss and Liverwort Association:

Along streams and the margins of ponds or in areas of humus soil kept wet by seepage.

Duckweed Association:

Made up of duckweeds, small floating plants on the surface of quiet pools.

Pondscum and Watersilk Associations:

Freshwater algae, free-floating or attached.

Pondweed Association:

Plants rooted to the bottom of ponds in water two to six feet deep. Not common, because ponds and lakes are few in the foothills.

Chapter 11

PLANTS OF THE TRUE MOUNTAINS

As distinguished from mesas and foothills, the higher land elevations may be thought of as the true mountains. In this "mountain country" are embraced the high peaks and passes, the forested ridges, gulches, and plateaus together with the higher of the open mountain parks; that is, the montane, sub-alpine, and alpine zones.

It is the "mountain country" which will most interest those who observe nature. However much one may enjoy the plants of plains and foothills these cannot or do not have the lasting charm of their mountain relatives. Perhaps this is because the higher altitudes are less often seen, or because they are particularly inviting at the time when the plains are parched and dry with the heat of summer. At any rate, the mere mention of Engelmann spruce, fringed gentians, Indian paint-brushes, columbines, and little-red-elephants (Plate I) will bring thoughts of cool winding trails, lakes fringed with natural gardens, and the glistening whiteness of snow banks, sheltered in the forest shade.

Forests of the "Mountain Country"

The montane region of Colorado is well wooded with spruce and pine forest, except in the parks. Engelmann spruces, often in pure stand, but sometimes with a mixture of sub-alpine fir, make a dense growth on north hill slopes and in sheltered canyons, while rock pine and lodgepole pine form the more open forest of drier situations. Wind-swept mountain tops and exposed ridges bear limber pine or bristle-cone pine, generally mixed with the lodgepole. The Douglas spruce occurs in canyons and on steep slopes. In many places there are close stands of the lodgepole pine, especially in areas which have been burned by forest fires. These various trees are all further discussed in the chapter on "Forests and Forest Trees."

Undergrowth in the Forests

Belonging to each type of forest, there are certain characteristic shrubs and herbs dependent upon differences in shade and moisture. The undergrowth associated with Engelmann spruce is not entirely different from that among rock pines or

under aspens, yet there is a real unlikeness. Many plants need considerable light; these will be found in the more open rock-pine forests, while true shade plants flourish among Engelmann spruces where, because of the weak light, the undergrowth is scanty and there is no danger of being crowded out through too much competition. Close stands of lodgepole pine are rather intermediate as to shade and moisture between rock-pine and spruce forests. Their undergrowth is made up of a mixture of

FIG. 79. Dwarf Cornel (at left). A beautiful low plant of marshland forest in high altitudes. The large white bracts surrounding the group of small flowers have the appearance of petals.

FIG. 80. Shrubby Cinquefoil (at right). A yellow-flowered shrub of moist soil in the mountains. Valuable for planting. One of the best and most-used native Colorado ornamentals.

shade plants and of those plants which need more light. The darker and moister forests afford suitable environment for the wintergreens, dwarf cornel, and many grasses; the twin flower is common, and also occasional orchids. But most common of all undergrowth is the blueberry which, however, produces little fruit. In somewhat drier and more open forests the blueberry plants are less abundant and of smaller size, yet they bear more freely.

Open forests of scattered pines have a rich and varied population of flowering plants. The more open the forest, the greater the number of flowers. In mountain parks, which are areas of grassland, sometimes with scattered trees, this profusion reaches its height. The parks are of such great interest that an entire chapter of this book is devoted to them. But even at the risk of saying the same thing twice, mention may be made of the great abundance in the parks of the Colorado loco-weed, mariposa lily, turret plant, beard-tongue, stone-crop, golden aster, mountain daisy, gaillardia, harebell, and yarrow. (For many of these see the colored plates.)

ASPEN GROVES

Aspens are common in the montane zone. They may form a fringe along the edge of a pine-spruce forest in a mountain park, or clothe scantily and in patches a barren south-sloping hillside, or they may occupy a seepage area of fertile, black, loamy soil.

The subordinate plants among the aspens differ, depending on the character of the soil and the density of the tree growth. For there are really two kinds of aspen forest. On gravelly slopes the low-spreading kinnikinik is usually found under the trees, together with gaillardia, cranesbill, golden aster, sulphur flowers, and a few dry-soil grasses. The trees are small and often widely spaced. In the more dense aspen woods of good soil and abundant moisture the tall undergrowth consists of grasses, meadow rue, brown-eyed Susan, yarrow, strawberry, sweet cicely, alpine milk-vetch, with often gaillardia and cranesbill as before.

PLANT ASSOCIATIONS OF WET AREAS

Streambanks and pondsides in the montane region show, as a rule, at least three plant associations· (a) Sedge swamp or moor, (b) Willow thicket and scrub, and (c) Grass meadow. As ponds dry up or as streams turn aside, the swamp changes to moor, the moor to willow scrub, the willow scrub to meadow. Such changes are slow but they occur with great certainty. Occasionally stoppage or reversal of this process takes place, as when a change in stream course brings more water than there was before.

Among the sedges of swamps or moor the beautiful rose-crown, a plant of the stone-crop family, is conspicuous for its pink

FIG. 81. Alpine Gold-flower, or Rydbergia. One of the commonest and most conspicuous plants above timberline.

flower-clusters in early summer and for its red leaves of August. Then there are the little-red-elephant, the heart-leaved bitter cress, and the shooting-star. Willow thicket, because of the dense shade, is not a favorable place for flowers but some of the plants just named may be present there in small numbers. It is the grass meadow in which the richest profusion of flowers occurs. Here are mountain daisies, asters, harebells, larkspur, blue-eyed grass, blue flax, paint-brushes, and a dozen others.

SHRUBS OF THE MONTANE ZONE

Shrubs of the montane life zone are not as a rule conspicuous, and yet they furnish a considerable list. A red-berried species of elder, the mountain maple, various kinds of currants, and the common wild raspberry are frequent along roads and trails. In wet places, willows, and a dwarf birch, the fly honeysuckle, and shrubby cinquefoil abound. On hillsides, often in rather shady places, there may be so many plants of the evergreen New Jersey tea or "mountain balm" that they can be said to form a "mountain balm society". The buffalo berry likewise, and the large flowering raspberry are locally conspicuous. Roses are present in open woods,—large-flowered and beautiful. The plants are, however, all low and small, so that roses do not form a conspicuous part of the flora.

INTEREST OF THE MONTANE ZONE

Considered, all in all, the montane life zone is of great interest and charm. The climate is cool, and with sufficient moisture to allow growth of plants similar to those in the mountains of New England or New York State. A visitor from the northeastern United States will feel much more at home, so far as the vegetation which he sees is concerned, in the montane than in any other life zone of Colorado.

THE SUB-ALPINE ZONE; ITS TREES

The sub-alpine zone of plant life may be recognized by the dwarfing of trees in exposed situations. It is the zone of heavy forests of Engelmann spruce, within approximate limits of 10,000 and 11,500 feet altitude. Its most upward extension is seen in the scrubby growth of pines and spruces known as "wind timber". The line where this thins out and finally disappears on the moun-

tain sides, is the boundary between the sub-alpine and the alpine zones. The sub-alpine forest has frequent open spaces, bright with columbines, Indian paint-brushes, and mountain daisies. As for trees, besides the Engelmann spruce, there may be limber pine, bristle-cone pine, lodgepole pine, and sub-alpine fir.

Many of the trees at high altitudes are twisted into fantastic shapes; the limber pines have trunks which lie along the ground and send stunted branches a few feet into the air. Of these

FIG. 82. Mountain Avens (at left). A handsome yellow-flowered plant common at timberline and above. (One-half natural size.)

FIG. 83. Bistort (at right). Narrow plants with spikes of white flowers. In moist soil at high altitudes, both above and below timberline. Sometimes called "wild buckwheat". (One-half natural size.)

various trees, the spruce and fir belong to moister soil, the pines to dry ridges. All are migrants from the montane zone.

THE HISTORICAL FACTOR IN TREE DISTRIBUTION

The present extension of trees in the Rocky Mountains may be explained by reference to the past. When the climate grew warmer toward the close of glacial times these trees began an upward migration. The seeds of spruce and fir, in particular, could easily be blown by the wind. They thus became placed in the bare spots recently covered with ice. But cone-bearing

trees are essentially social in their habits; they need the protection of their fellows, especially where the environment is so unfavorable. Hence only those seedlings which sprang up near some parent-tree were successful. The others died. Small saplings would not afford much shelter; only trees which had lived twenty-five to fifty years could play the role of nurse. So the upward progress was very slow. It might take centuries for the vanguard to advance even a few hundred feet up the mountain side.

TIMBERLINE

The higher up in the mountains, the more austere are the conditions. Cold climate, short seasons, and high winds conspire against all life. Probably no trees could withstand the climate of the tops of the highest peaks. But timberline is far below the alpine summits. Is it certain that the trees have now gone as high as they can? May they not reach to higher altitudes in the centuries to come, even with no change in climate? These questions may now be considered, in view of evidence which the trees themselves present.

If one examine closely the limber pines at timberline it will be found that there are many young trees lying dead upon the ground, along with the present living trees. Some of the dead trees are old,—one hundred or two hundred years. Remains of trees, dead centuries ago, may also be found. These dead trees sometimes occur higher up on the mountain than the living ones. This means, of course, that the upper timber limit of today is no higher than it was hundreds of years ago,—perhaps even lower. The trees in times past advanced from century to century as they were able, but the severe cold and winds killed many of them. Only the strongest or the most favored in situation survived. In time, however, the advance halted. Some trees, contending with the unfavorable environment, lived for a period beyond the limit thus far established but, in time, a particularly severe season killed them, and timberline was thus pushed back down the slope.

The history of the sub-alpine scrub is written plainly on the mountain sides, yet few people who think they know the mountains have read it. Timberline is casually thought of as the limit of tree growth—why there should be a timberline at all and why it occurs as it does are questions seldom asked.

The upper limit of spruces and firs shows a different history from that of the pines. It will be remembered that spruces and firs grow in the moister situations. They belong more to sheltered places, glacial cirques, and steep canyons. These stations have been free from ice only a comparatively short time,—a few thousand years. In fact, some glaciers and permanent snow fields still exist in hollows and protected areas.

The spruces and firs, because they have not had so long a time as the pines to work their way up the mountains may not have gone as far as the climate permits. From observations made on different peaks this seems to be the case. Usually, though not always, the outposts are beyond any dead timber. The spruce and fir trees are still advancing. So while there is

FIG. 84. *A*. Eight-petaled Dryad. A prostrate half-shrub of dry rocky places above timberline. *B*. Alpine Clover, one of a number of species of this genus (Trifolium) which grow at high altitudes. (Both about one-half natural size.)

a spruce-fir timberline it is not at the permanent climatic limit of tree growth as is the timberline of limber pines. Its position is determined by historic factors rather than by climatic ones. Sometime—perhaps in a thousand years, perhaps in ten times or a thousand times as far in the future—these trees will also reach their climatic limit, a line beyond which the elements will say: "Thus far shalt thou go and no farther".

In general aspect, the dwarfed spruces and firs form a very different type of vegetation from that of the pine. Often the trees are closely placed together, thus protecting one another, and the much-matted branches form a dense cover ten to twenty feet high. This growth is sometimes so close and firm that one can walk around on top of it well above the ground, without falling through.

"Wind-rows" are common. These are of stunted trees, densely placed, extending from west to east in a belt ten to twenty feet wide. High winds all come from the west. They kill the branches which start to grow out toward the source of the wind, and they twist the side branches around and make them turn to the east. Thus the branches from north, east and south sides of the tree all are turned to the east. This makes a dense growth to the lee side which serves to shelter the next tree. At the west end of such a wind-row the trees are perhaps, two feet tall, while at the east end of the row they may be twenty feet. Seen from north or south, the row of trees has the appearance of a long, low shed with sloping roof.

Patches of isolated wind timber sometimes exists a long way above any continuous area of trees. Such patches occur in sheltered places, in depressions where wind does not have its usual sweep, or where moisture conditions are especially favorable. A few trees may get started in the shelter of rocks which protect them until they are old enough to have considerable endurance of their own. From these, as a starting point, a colony of trees may develop, spreading in all directions.

Just what may be called timberline is sometimes hard to decide. For present purposes, however, it will be convenient to establish the line where the larger masses of wind-blown timber cease, and only small isolated areas of scrub continue. On the north slopes of mountains, timberline is lower than on the south; for it is colder and the winds more severe. In the southern part of Colorado, 12,000 feet is usually stated to be the timberline but in the northern part of the State timberline is 500 feet lower. In Montana and Alberta, it is as low as 9,000 or even 7,000 feet in altitude above the sea.

DWARF WILLOWS OF THE HIGH ALTITUDES

Forests of large Engelmann spruces occupy the lower part of the sub-alpine region, while dwarfed timber is the most conspicuous element in the higher reaches. But there are various smaller plants also of interest. In the moister places, and along streamlets, many dwarf willows occur, some of them being the same species that grow up to the mountain tops. The willows are smaller here than in the montane zone but are larger than those

FIG. 85. Some Plants of the Gentian Family. *A*. Turret Plant, Deer's Tongue, or Green Gentian; mountain districts. *B*. Tulip Gentian, or Eustoma; in alluvial soil near streams close to the foothills. The tulip gentian is becoming rare; it should not be picked. *C*. Love Gentian, or Amarella; a small plant of high altitudes; flowers purple. *D*. Fringed Gentian; in the montane and sub-alpine zones. This and the tulip gentian have handsome, clear, blue flowers. Both are rare.

of the alpine heights. One of the handsomest is the sage willow (*Salix glaucops*) a very dwarf shrub with whitish-green leaves.

Flowering Herbs of the Sub-alpine Zone

Among plants with conspicuous flowers, the species of Jacob's ladder are characteristic of the sub-alpine zone, though they extend also for a distance into the true alpine heights and down within the montane zone. But they are best seen with the wind timber of high altitudes. Plants with handsome, deep pure-blue flowers they are, and with greatly divided leaves. They have no hairiness of stem nor dwarf habit, as might be expected because of the cold climate, but instead are tender and delicate, just as other shade plants. This is, after all, not so strange, for the shade of the sub-alpine scrub is very dense, and these plants are well protected from sun and wind.

Another sub-alpine plant, but one which grows in moist places, is the rose-crown. It belongs to the stone-crop family and has the usual thick, juicy stem and leaves so characteristic of that group of plants. Like most sub-alpine plants it ranges both up and down beyond the limits of the zone. When down in the montane region it grows in cold, wet soil, along streams or near lakes. In the alpine regions it may exist in drier soil. The supply of water determines its tallness, for in wet places it may be a foot high, but in dry places perhaps not three inches.

The sub-alpine scrub extends up in many places in the form of tongues to a great distance above any recognizable timber belt. Between these tongues of thicket or forest there are beautiful sunlit reaches where flowers bloom in profusion for a short two months after the last snows of May and before the early storms of September. Often much swampy or boggy ground is met with in these openings, the moisture coming as seepage from higher parts of the mountain side.

Open country of the sub-alpine zone is much the same as open country higher up. There are the drier ridges and rocky slopes with low, matted plants and the moister areas of greater luxuriance. In these moist places the green of grasses and sedges is sometimes quite masked by the sulphur yellow of Indian paint-brush or the blue and purple of harebells, beard-tongue, and mountain daisy. (See Plates I and II.)

Sub-alpine Plants fit into their Environment

In some respects sub-alpine plants are more interesting than all others. In the sub-alpine district, better than anywhere else,

one can recognize the importance of environment for plants. The stunted wind-blown trees, the dwarfed flowering herbs on dry ledges, the more robust plants in moist places, the delicate growths upon shaded ground under the trees,—all these suggest the relation of plant to soil and general surroundings. All show how well plants fit the niches which nature has provided for them.*

FIG. 86. Two interesting Alpine Plants. *A.* Star-of-Bethlehem, or Lloydia; a lily with greenish-white flowers. It does not look like an "alpine" plant. *B.* Narrow-leaved Primrose. The flowers are crimson and very large in proportion to the rest of the plant.

PLANTS OF ALPINE HEIGHTS

A peculiar charm inheres to the plants of true alpine districts. This is partly on account of the difficulty in reaching such situations, so that the flowers remain at all times somewhat unfamiliar, but still more because of the natural beauty and delicacy of many of the blossoms themselves. One must admire the sturdiness and hardihood of these plants which withstand the storm and

*Lest the reader imagine that plants are like pieces of putty to be molded into any shape by the environment, it might be well to re-read in this connection the chapter dealing with "Life Zones and Altitude".

cold successfully and are able to produce their wealth of sweet-scented loveliness.

It is quite out of the question to give in a dozen short paragraphs any full account of alpine plants, but a few of those may be mentioned which are most interesting or conspicuous. It will be sufficient to name: forget-me-not, alpine gold-flower, harebell, fuzzy thistle, phlox, alpine clovers, mountain avens, eight-petaled dryad, giant-rooted spring-beauty, bistort, and mountain pink.

Forget-me-nots need no description as to their flower, since they will be recognized by all who know the cultivated plant of that name. Our mountain forget-me-nots are "cushion plants" which spread out upon the ground as low mats about the size of a man's hand. They have flowers of clearest blue, while the leaves and much-branched stems are woolly white. The leaves are scarcely seen at blossom time because of the abundant flowers. A single plant, hardly a half-inch in height, may bear a hundred blossoms of unforgettable blueness, and these cover up completely all there is of stems and foliage.

The alpine gold-flower (Rydbergia) is among the most striking in appearance of high-altitude plants. The flower-head resembles somewhat that of a sunflower; indeed, the plant belongs to the same family. The rays, instead of being orange in color are of the purest yellow. The center is light orange-brown. Like many alpine plants the gold-flower has white, fuzzy stems; this feature as well as the brilliant light yellow of the rays tells at once that it is not an ordinary sunflower. Gold-flowers are so common in many places that they color wide areas of the landscape. An alpine meadow in July means a field yellow with gold-flowers, yet having a few other small and less conspicuous plants perhaps hidden away under these dominant members of the plant community. (Fig. 81.)

Harebells need little mention; everyone knows them. In high altitudes they bloom profusely, the flowers are large and of a rich blue color. In late summer these are as conspicuous as were the gold-flowers a month before. They seem to take full possession of the moist places and obscure everything else. One would scarcely find a frailer or more delicate plant, yet the harebell withstands the cold of alpine nights or the bright sunshine and heat of day without any special structures which would seem to

FIG. 87. Parry's Primrose. Purple-flowered plants of marshy ground in sub-alpine and alpine zones. Of unpleasant odor.

protect it. The harebell is one of the few plants suited to all the climates from foothills to highest peaks.

The fuzzy thistle is never very common, but a few specimens are found wherever one goes on the mountain tops or on the crest of the Continental Divide. The extreme fuzziness of the plant distinguishes it from the ordinary kinds of thistle at lower altitudes.

Alpine clovers have leaflets which are more narrow and less rounded than the leaflets of common white clover of our lawns. The flower-clusters have rather few flowers, but the individual flowers are larger than are those of cultivated species. Wild bees are frequent visitors for nectar, and a patch of alpine clover is often first recognized by the buzzing of the insects which gather about it. The flowers of most of these clovers are pink and they are often quite fragrant.

The mountain avens is a low-growing plant of the rose family noticeable for its compound leaves of many leaflets, reminding one of a diminutive sumac. The plants grow in moderately moist soil, and often in great profusion. In late summer, the leaves turn red and the plants are then almost as conspicuous as they were earlier in the season when covered with bright yellow blossoms. The flowers of mountain avens are typical of the rose family; with five sepals, five petals, many stamens, and many pistils. Between the sepals, there are alternating small bracts, as in the strawberry, thus giving an appearance of ten sepals instead of five.

The eight-petaled dryad is an alpine plant of special interest because it occurs not only in the Rocky Mountains but also in Greenland, Alaska, and the White Mountains of New Hampshire. It is not a true cushion plant, but forms a very flat mat of small thick wavy-margined leaves close to the ground. When in blossom, there is an abundance of glistening white flowers. The dryad belongs to the rose family, the flowers of which usually have five petals, and it is very much like other members of the family such as cinquefoil and mountain avens, although it has eight-petaled flowers. Such departures from typical structure occur in various plant families but they are rare. Most families of plants have a definite pattern, the essentials of which are adhered to very closely. (Fig. 84.)

Spring-beauties of the genus Claytonia grow at various alti-

tudes in Colorado but the giant-rooted spring-beauty keeps to the alpine heights and is one of the most frequent plants of bald summits. The flowers at once proclaim it a spring-beauty but the leaves are broad, very little like those of plants belonging to the same genus in lower altitudes. The leaves are, however, thick and fleshy as is to be expected in members of the purslane, or Portulaca, family. Late in summer the leaves often turn scarlet, and the plants are very conspicuous objects projecting from cracks between rocks, or firmly anchored by their enormous roots in some little patch of gravelly soil.

FIG. 88. Blueberry, in blossom. Blueberry bushes in Colorado are small and low-growing. The flowers are pink. The bushes are very abundant as an undergrowth in Engelmann spruce forests.

The bistort is a kind of smartweed which grows in the moister places below snow banks and in depressions, at high altitudes. The plant has narrow leaves and a spike of small flowers, usually white but occasionally tinged with pink. When thus colored, it resembles the common lady's-thumb smartweed of the eastern United States. Bistort remains in blossom for many weeks, so that one is likely to see it at any time when visiting the alpine heights. (Fig. 83.)

Mountain pink grows in clumps or mats. Stems are short and very much branched; a profusion of small pink flowers covers

the entire plant at blossom time. The flowers are much like the cultivated catch-fly and sweet-William but they are smaller. The mountain pink is a typical cushion plant, affording an illustration of one of the best-marked growth-forms occurring in the alpine vegetation. It shows the densely matted dwarf habit and profusion of flowers so common among species of dry situations above timberline. Phloxes, forget-me-nots, certain sandworts, and whitlow-wort have this same cushion form.

DRY AND MOIST AREAS IN THE ALPINE REGIONS; THEIR PLANTS

There are two distinct habitats for plants in the high altitudes. These are (a) the ridges, or rock ledges, which are dry and windswept, and (b) the moister depressions and valleys which are more protected. In the first-named localities grow the densely matted plants with short, much-branched stems, while in the more moist places there are taller species, some of which, as the harebell, may not show any peculiarities of structure which would distinguish them as plants of alpine heights. The mat and cushion plants bloom in early summer, while plants of moister places do not come to flower until July or August.

In many parts of the alpine country there are alternating patches of dry and wet soil. The general aspect of an area may be that of moist tundra, with sedges, gold-flower, mountain avens, paint-brush, bistort, and harebell; but here and there a dry "island" occurs, covered with mat and cushion plants. Long white hillside meadows of bistort, or yellow bands of mountain avens growing in moist soil may give place to forget-me-not, mountain pink, and alpine clover upon the dry, coarse, disintegrated granite.

GEOGRAPHICAL DISTRIBUTION OF ALPINE PLANTS

Certain species of alpine plants grow only on the highest and most exposed peaks, and do not come down as low as the passes or saddles between the peaks. A patch of such plants on Long's Peak may have its nearest counterpart on Mt. Audubon twenty miles away. How did these plants become placed there? Were seeds carried by the wind or by birds?

In discussing the plants of lakes and pondsides it was found necessary to bring in birds as the active agents of seed distribution. Wading birds might carry seeds from lake to lake in mud attached

to feet or feathers. But such a distribution of alpine plants is out of the question. There are almost no birds at all in the alpine region and there is little mud there. Seeds could not be carried

FIG. 89. Adonis Buttercup. These handsome flowers are found close to alpine snowbanks.

by birds in food as are the seeds of berries, for the alpine plants do not produce such fleshy fruits. Wind distribution of seeds from peak to peak is not to be considered seriously because few

alpine plants have seeds that are light enough to be carried long distances. Of course the seeds are not distributed by water from peak to peak as they may be carried by streams from one place to another in low altitudes. Indeed, unless viewed from the historical standpoint, the question will be a difficult one to answer.

Geologists state,—and there is abundant evidence to support what they say,—that during the glacial epoch all of the present peaks and passes were under ice, together with much of the ground down to 9,000 feet altitude. In the depressions there were glaciers even lower down. There were, of course, no plants in the parts covered by ice, but at somewhat lower altitudes,—7,000 to 9,000 feet—plants could exist, for the climate was such as at present obtains at the bases of the high peaks. This region, which is now the lower montane zone, was at that time alpine in its vegetation. Its plants were distributed continuously all along the east and west sides of the Range.

With the coming of warmer climatic conditions the glaciers disappeared so that now there are only a dozen left in the whole state of Colorado, although glaciers are still large and numerous in Montana and in the Canadian Rockies. As the glaciers disappeared, the ground which they formerly occupied became open to vegetation. Plants migrated into these areas where climatic conditions were the same as those which they had just been experiencing at lower altitudes during the glacial period. With further warming up of the climate they migrated higher and higher each year or each century. Finally, instead of forming a continuous zone all along at the foot of the main range, the alpine plants became isolated on the several mountain tops. And so they are scattered at the present day on peaks all the way from Arizona to Alaska and even into Europe. If there had been no glacial epoch there could not have been this present-day distribution of alpine plants.

General Features of Alpine Vegetation

Now that a few individual kinds of alpine plants and something of their history have been considered, a glance may be taken at the general aspect of alpine vegetation. In the first place, it is to be remembered that what is called the alpine zone of plant life is above the limit of timber. Hence there are no

trees. The only shrubs are dwarf willows. It is an open country. In places there are huge stones, from the size of a large packing box to that of a dwelling house, but more often wide areas of gravel-like broken rock and coarse sand dotted with shallow pools; or again granite ledges, cliffs, and moist hillsides. Snow fields exist in sheltered cirques, and there are small lakes which mirror the white clouds or the deep blue of the mountain sky.

But what has all this to do with the flora? Very much indeed, for plants must fit into the physical features of the region where they grow. The steep cirques with walls of solid granite and an accumulation of coarse talus below, offer little opportunity for plants to get a foothold. Some species grow rooted in the crevices of rock, and there are often lichens in abundance on surfaces long exposed to the weather—but good black soil there is none. At the bottom of a cirque there may be a small rock-bound lake. At places along the shores of the lake there will be some accumulation of soil. Here are well-rooted plants of good size, such as the beautiful Parry's primrose, and also various sedges and grasses.

Shallow basins and undrained flat areas on the hill crests and the top of the Continental Divide have a flora of great attractiveness and beauty. These have sometimes been called "mountain meadows" but they are really flower gardens—not meadows at all. Brilliant with a profusion of red, yellow, blue, and purple blossoms these flower gardens are the delight and wonder of all who visit the mountain tops.

THE TUNDRA

Even on a first visit to high altitudes it is possible to recognize the plant communities which have been considered. These are: (a) Moist tundra; (b) Dry tundra. The moist tundra exhibits many aspects in which now this, now that group of species is prominent. In like manner, different parts of the dry tundra have very different appearances.

* * * * * *

If an attempt is made to see these various groups of plants and to consider the plants in each community it will be far more interesting than simply to hunt out the names of certain individual species. Many good botanists, as a matter of fact, do not pretend

to know a great number of plant names. They consider it of more consequence to know the plants themselves—their habits, peculiarities in structure, and manner of life,—than to know the names which have been conferred upon them. To know plants, it is necessary to live out of doors all summer long. One should enjoy the sunshine of mountain peak and the cool shade of the forest, the babbling of meadow brook and thunder of mountain torrent. Only the attitude of the outdoor poet who loves nature for its own sake will serve the man or woman who would really learn the life of plants.

PLANT ASSOCIATIONS OF THE TRUE MOUNTAINS

Forest Associations

Englemann Spruce Forest:

Sometimes a pure stand of Engelmann spruce but frequently with an admixture of true fir at higher levels and Douglas fir lower down. Very little undergrowth as a rule but blueberry rather common, with Viburnum, mountain-ash, and Juneberry infrequent. The common forest of high altitudes.

Pine Forests:

In drier soil than the spruces. It is usual to recognize the Lodgepole Pine consociation, the Limber Pine consociation, and Bristle-cone Pine consociation. Open places in any of these forests at moderate montane altitudes will show such shrubs as roses, buffalo berries, evergreen Ceanothus or New Jersey tea ("mountain balm"), Juneberry, and choke-cherry. In the sub-alpine zone the shrubs are absent, and the plants of the forest floor are chiefly such as occur in dry grassland.

Aspen Forest:

An important plant community of the montane zone and sparingly represented in the sub-alpine zone. Under the aspen trees there is usually a growth of meadow plants more like foothill meadow than like the meadow of high altitudes.

Thicket and Scrub

Alder-Willow Thicket:

Close to streams or in swampy soil. The alder (*Alnus tenuifolia*) and various species of willow are the conspicuous plants while the undergrowth consists of marsh grasses, umbellifers, and a mixture of moor and meadow plants.

Willow-Birch-Honeysuckle Scrub:

Similar to the Alder-Willow Thicket but composed of smaller shrubs. The fly honeysuckle (*Lonicera involucrata*) is frequent at moderate altitudes but absent in higher parts of the sub-alpine zone.

Shrubby Cinquefoil Community:

Widely distributed in altitude and developing in almost any kind of soil. The interspaces between the shrubs have usually the composition of meadow but less frequently they are like dry grassland.

Herb Associations (Grassland)

Lichen Association:

Confined to rocks and coarse soil, chiefly on wind-swept ridges and mountain summits where there is little vegetation.

Mat and Cushion Association:

On dry exposed ridges in coarse and sterile soil. Best developed above timberline. Mountain forget-me-not (Eritrichium), mountain pink (*Silene acaulis*), and mountain phlox are characteristic. As this association becomes more mesophytic, dry grassland results.

Dry Grassland Associations:

Developed in open parks, on hillsides, and in forest openings of pine growth. Many grasses and sedges are present, with members of the chickweed, mustard, borage, and composite families.

Mountain Meadow Association:

Occurring at all mountain altitudes except on the highest peaks. The characteristic plants are flowering herbs and grasses, with few sedges. Meadows differ in species at the various altitudes but usually they include such plants as Indian paint-brush, mountain daisy, harebell, and (above timberline) the mountain gold-flower (Rydbergia) and mountain clovers (Trifolium).

Yellow Waterlily Association:

In a few mountain lakes of shallow depth and muddy bottom. The species is *Nymphaea polysepala*.

Pondweed Association:

Attached plants (Potamogeton) with floating leaves in moderately shallow water of ponds. Not found much above 10,000 feet elevation.

Bur-grass Association:

Attached, partially submersed plants (Sparganium) with long leaves and weak stems. In shallow water with muddy bottom.

Algal Associations:

Floating on still water or occurring as plankton in the water. Some of these associations have their plants attached in mud, or held to stones in running streams.

Duckweed Association:

Formed of small plants, duckweeds (Lemna), floating on the surface of quiet water in the montane life zone but not, so far as known, at higher altitudes.

Spikerush-Buttercup Association:

On muddy or sandy stream flats at moderate montane altitudes. The plants sometimes grow out into the water of streams and ponds. Besides spikerush and buttercups there are usually some grasses. This association easily passes over to sedge moor.

Mountain Sedge Associations:

Sedge moors are developed especially in wet acid soil and are characterized by sedges of the genus Carex. Common plants other than sedges are the marsh marigold, little-red-elephant, Ligusticum, and the rose-crown (Clementsia). As sedge moor becomes drier, through building up of vegetation and consequent better drainage, it becomes meadow. Besides typical sedge moor, there are sedge swamps and dry sedgeland. The moor shows great diversities in floral composition. In favorable places for study it is separable into moss moor, sedge moor (in the strict sense), willow moor, rush moor, and meadow moor. (For details of sedgeland vegetation, see the author's papers on "Role of Sedges" and "Sub-alpine Lake-Shore Vegetation", listed in the bibliography, Appendix III.)

Chapter 12

GRASSES AND GRASS-LIKE PLANTS

The importance of grasses to man is very great. Rice, barley, and wheat were grown in Asia before recorded history. The earliest civilized Europeans used wheat and barley, the "corn" of ancient peoples. In classical times rye became known and in early modern times oats gained an important place in the northern countries of Europe. Through a hundred centuries man has used grain as food for himself and as feed for his animals. Even the wild grasses of meadow and prairie he has made use of for pasturing his sheep and cattle.

There are no wild grasses which we can be sure were the original forms of rice or corn, nor do we know through just what steps our other grains have evolved to their present state. It is certain, however, that primitive man in seeking food would sometimes eat the grains of wild grass, and when he wished to grow a crop under cultivation he would learn to select for seed the largest grains or the grains from the largest plants. Even with the crude and often unintended selection of seed as practiced by savages and barbarous peoples, new and better varieties would from time to time become established. At the present time, scientific agriculture is constantly bringing forth improved strains of wheat and other grains adapted to special climatic and soil conditions, and such as have a resistance to rust or other disease.

The Structure of a Grass Plant

Although in common parlance any kind of plant with long, narrow leaves may be called a grass, yet true grasses are distinguished from various grass-like plants. Star-grass and blue-eyed-grass show by their colored flowers that they are not grasses at all. No true grass has flowers with petals, although certain ones show some color due to orange or red stamens. The sedges, some of which may be harvested with marsh hay, are not always easy to distinguish from grasses, for they too have inconspicuous flowers of green. The stems, however, differ from those of grasses; they are not jointed in the same way, nor are they hollow, and the leaves are differently arranged. Sedges usually have three-angled stems, and commonly grow in moist places.

The true grasses have the stems jointed—as seen in wheat, Indian corn, and bamboo. Nodes, these joints are called; they are often swollen and hard. The part of the stem between any two nodes is named the internode; in most grasses it is hollow, while

FIG. 90. Wild Rye. Frequent on hillsides and creek-banks.

the node is solid,—as in a cane fishing-pole. If the top of a grass is pulled, the stem separates just above a node, and the young growing end of the internode is drawn out. Many people pull apart the stems of blue grass or timothy as they walk along a country road and eat the sweet, tender tips which are thus exposed.

The jointed structure of grass stems is useful to the plant in case of injury. Grasses can grow at all of the nodes, while most plants can increase in length only at the tip of the stem. If growing wheat plants are laid prostrate by a storm or by tramping, the upper part of the stem will become erect. This change is brought about by growth at the nodes. The unusual position in which the stem is placed seems to stimulate the nodes to activity, and the plant soon is upright.

Grass leaves are parallel veined, the chief veins passing the long way of the leaf. The so-called "veins" received their name long before they were well understood; it was thought that they were of the same nature as the veins of animals. And they do correspond, in a rough way, to veins in animals, since they carry liquid. This liquid, the sap, is really water with a very small amount of mineral and organic materials in solution.

Veins serve not only as sap channels but they give strength and stiffness to the leaf. In the stem also, the vascular bundles which correspond to leaf veins, furnish support to soft parts. Leaf veins consist of long tubes, vessels, spindle-shaped cells, and fibers. These same elements make up the woody parts of trees and shrubs. The smaller veins converge at the base of the leaf into a few large veins, or vascular bundles, which then pass down the stem and into the root. Thus there is a continuous system of tubes extending the whole length of the plant. When water is absorbed by the root hairs it passes through the root, upward in the stem, and finally into the leaves by means of the vascular bundles and veins. In the leaves the water, or sap as it has now become, diffuses into all parts of the soft structure and bathes the living substance, keeping it in a proper condition of moisture. Water is being continually evaporated, or transpired, from the leaves; leaves would soon wilt but for the continual supply of water which passes up to them through the leaf-veins and the vascular bundles of stem and root; all of this water comes, to begin with, from the soil.

The stems of grasses have their vascular bundles scattered throughout the soft parts, not arranged in a single ring as is the case with stems of sunflowers, beard-tongues, mints, and others. In arrangement of bundles the grasses resemble lilies, orchids, irids, and other plants with long parallel-veined leaves. This

similarity in stem structure is one of the features which leads the botanist to classify such plants together as relatives, and to separate them from the plants with a single circle of bundles surrounding a central pith.

If a thin section of a grass stem be examined under the compound microscope it will be found that the vascular bundles have

FIG. 91. Blue-stem, or Three-top (at left). Some of the species of this genus (Andropogon) are common bunch grasses of the plains.

FIG. 92. Wild Mountain Timothy (at right). This is not the cultivated timothy "gone wild" and grown smaller but a native grass of the higher altitudes.

a characteristic structure, with two main parts. The larger part is made up of the tubes and long cells which have already been referred to as serving to carry sap upward through the plant. These correspond to wood of trees and may be called wood. There are also other narrower tubes and cells which act as food channels and which distribute food material to various parts of the plant, taking it from the leaves where it is formed in the presence of sunlight by the green living substance of the leaf.

An individual grass leaf may be very long and, unlike a maple or cottonwood leaf, it continues to lengthen all summer,

for the basal part of the leaf-blade is capable of active growth. Hence grass leaves in the autumn are longer than those of spring, while the leaves of most plants reach full size very early in the season.

Flowers of Grasses

Many persons who have an acquaintance with flowers of more conspicuous appearance do not recognize the flowers of grasses or know about their parts. Yet it is not hard to gain an understanding of the grass flower. Wheat grass will serve to illustrate the structure. The entire plume or spike (the "inflorescence") consists of many flowers arranged in spikelets. Each spikelet is a short branch with two small scales, or glumes, at its base. Partly inclosed between these glumes are the flowers; two, three, four, or five in number. But these are very different from the flower of a lily or a rose or a buttercup, for they have no true petals or sepals, yet since stamens and pistil are present we know that they are flowers. Each flower of wheat grass has two small green scales which fit together closely and enfold the pistil and stamens. The larger of these two scales is called the lemma and the other the palet. If one wishes to study these flowers one must be sure to collect them on various days, since stamens and pistil ripen at different times. When these essential organs are once recognized, with their relation to lemma and palet, the grass flower is understood and need cause no difficulty. (Fig. 96.)

Common Grasses

The grasses of Colorado and of the Rocky Mountains are of many genera and many species. Most of them have near relatives in the eastern United States and a few are identical with eastern species. Wheat grasses, wild rye, foxtail, bromes, three-top, rattle-snake grass, buffalo grass, and grama grass are common, and easily recognized after a little acquaintance. Reference may be made to any illustrated flora for figures of common grasses.

Beards of Grasses; Inheritance

Among cultivated wheats, some are bearded and others not bearded; wild grasses also show differences with regard to the beard. The beard consists of bristles, one from each lemma. Usually the bristle, or awn as the botanist would call it, projects from the tip of the lemma, but in oats it is attached to the rounded

back of the lemma. When no beard is present, the lemmas of the several flowers are short pointed or rounded at the tip. It is an interesting fact that when beardless and bearded wheat are crossed, the first hybrid generation is without awns. As the student of Mendelian heredity would say: beardlessness is dominant to the

FIG. 93. A small Sedge of the Genus Carex (at left). Present in moors and meadows at various altitudes.

FIG. 94. Bulrush (at right). A tall marsh plant of somewhat grass-like appearance. It occurs in the lower altitudes.

bearded condition. If the beardless hybrids are self pollinated, they produce again in the next generation both of the original types. The ability to form beards was not lost, but merely covered up or hidden.

"ESCAPES" FROM CULTIVATION

Cultivated grains sometimes grow along highways and railroad tracks. Among the commonest are wheat and oats, but barley and rye also may be found. They do not form a permanent

part of the vegetation as timothy often does, since they are but annual plants. These "escapes" are not to be confused with true wild oats, wild rye, wild barley, and the various wild wheat grasses.

The Grasses of Colorado

In all, there are known in Colorado 270 different species of grasses. Some are wide-spread, others rare or occasional. Many are confined to the plains region, some occur only above timber-line, but most are found to range for at least a few thousand feet up and down. Considered as a whole, the grasses are a very interesting family and one of the most valuable in our flora. Further consideration of some of the commoner forms is given at the close of this chapter.

Sedges of the Genus Carex

Of plants commonly called grasses and yet not members of the grass family, the most common are sedges of the genus Carex. These plants are extremely grass-like in appearance, whether seen singly or growing together. Yet, as already suggested, there are differences which can be detected with little trouble. Grass stems are cylindrical, sedge stems are usually three-angled. The leaves of grasses are placed on the stem in two rows, as is easily seen if a single grass plant is held by its top and viewed from above. Sedges have three rows of leaves upon the stem. But of botanical features which distinguish grasses and sedges, the flower-structure is most important. In grasses the upper part of the pistil consists of two branches, the stigmas, while sedges have commonly three stigmas. Such a difference in the flower may seem insignificant to the non-botanist but it has been found that flower structure is so constant throughout large groups of plants that it is more to be relied upon as an index of relationship than are features of stems and leaves.

Sedges are common in wet meadows, swamps, and moors. Curiously enough, there are also some species in dry situations, so abundant in places that they form a substantial sod. Among the earliest green sprouts to appear in spring on mesas and lower foothills are the new shoots of a species of Carex. For the most part, the different kinds of Carex grow in poor soil. Usually it is cold, wet, and frequently undrained. The plants are especially

common at high altitudes. The xerophytic species occur in coarse soil, especially in decomposed granite. Well-drained soils of good texture are favorable to grasses, and if grasses are present the sedges make little headway in becoming established. The sedges are "poor fighters".

The very great number of species of sedges of the genus Carex in Colorado and elsewhere in the world makes the plants difficult to study. Indeed, Carex has the reputation, among botanists everywhere, of being a "difficult" genus. Differences among the various species are clearly seen by a specialist, but few people can qualify as specialists in the genus Carex. To botanists who are not Carex specialists, the different forms

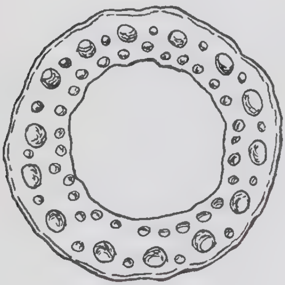


FIG. 95. Cross-section of Grass Stem (at left). The diagram shows the hollow center and the numerous vascular bundles through which water and food are conducted.

FIG. 96. Grass Flower (at right). The pistil is in the center, next are the three stamens, then the palet (smaller scale) and the lemma (larger scale).

seem to make a vast array of plants grading into one another and so much alike that they confuse and bewilder. Perhaps many of the species are of comparatively recent origin; the genus is one of those in which evolution has taken advantage of the many and various possible permutations of a few structures. The features which distinguish the several groups of species have to do chiefly with the flowers and fruit, more especially the fruits. These may be flattened or swollen, small or large, triangular or lens-shaped, the individual fruits may be closely placed or far apart, with a long "beak" or with a short one or not any at all. Then the individual species of these groups differ in tallness of plant,

width of leaves, general robustness, time of flowering, whether spreading by under-ground stems or not, and in various other minor details. No genus of plants furnishes a better illustration of the production of many species by variation of a few characters. And at the same time, these variations are so slight that all species of Carex are greatly alike. Every Carex is a Carex and can not be mistaken for anything else.

Sedges as Pioneer Plants; Succession

Sedges are important in conversion of ponds to dry land; they are pioneer plants in the series of plant communities which develop in water, or upon wet ground. Semi-aquatic species, growing in shallow water, decay each year; as the plants settle to the bottom they render the water still shallower. The zone of half-submersed plants which fringes the pond-margin advances slowly to what was formerly deeper water. The semi-aquatic plants are pressed upon by species which grow in muddy or soggy soil; and these are crowded forward by the grasses and herbs of ordinary soil. Sedges build up ground which is at first very wet and after years or centuries, make it higher, drier, and better-drained. A pond changes to marsh, marsh gradually is converted to moor and then to meadow. The meadow at first is a mixture of sedge and grass but the sedges gradually die out as grasses become more numerous. At last, following the meadow stage, there is usually a forest. This series of changes in vegetation is a *succession* and since it starts with water it is called hydrarch succession (that is, "originating in water".)

In dry ground, where sedges sometimes abound, these plants improve the coarse soil and prepare it for grasses or for forest. The decayed plant-remains, year after year, form humus which, with sand and other mineral parts of the soil, makes loam. The loam holds water for a longer time than soil without humus and is suitable for grasses and many flowering herbs. These could not grow in the soil which was previously of such poor quality. And so, largely through the growth of sedges, a sterile soil is, in time, rendered fertile; a hillside or mesa-top which supported only a sparse growth of plants may, after a long period, become meadow grassland. This, in turn, may give way to a growth of shrubs or finally to a forest. Since the vegetation of the ridge was at first

that of a dry situation, the progressive changes form a xerarch succession (i. e. one originating in dry soil).

Sedges contribute to the productiveness of the land and to the development of higher types of plant communities. In doing so they cause their own effacement. They are pioneers, and like pioneer men, they can not flourish long in any one place; they themselves bring about conditions which are no longer suitable for pioneers.

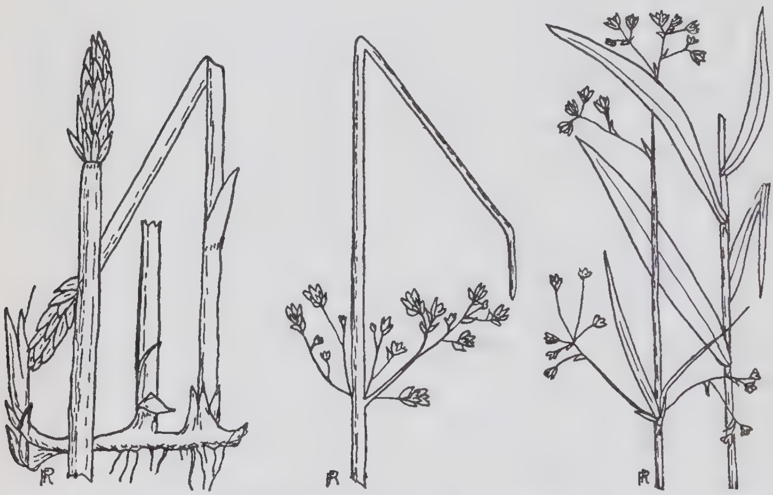


FIG. 97. Spikerush (at left). This and other spikerushes live in very wet ground, sometimes half-submersed at the edge of a pond.

FIG. 98. Rush (middle). Rushes are plants with smooth, round stems, small inconspicuous flowers, and practically no leaves at all. Twenty-two species are known within the borders of the State.

FIG. 99. Woodrush (at right). A delicate plant of moist and shady situations.

BULRUSH AND SPIKERUSH

Little need be said of sedges which do not belong to the genus Carex. The bulrush and spikerushes of pond margins are familiar to many. They also are engaged in changing ponds and lakes to dry land. They take part, however, in only the early stages, and are followed by the commoner sedges which have just been considered. (Figs. 94 and 97.)

The Spikerushes are not so very grasslike in appearance, since their leaves are very small or almost absent. In them the work of food making is done by the stems. They are found in

shallow water, the reflection from which is added to the direct light, and so the sum total of light received is very great. It is thus possible to get all of the radiant energy needed without the display of leaf surface.

The True Rushes

The Rush Family, made up of the common rushes and the wood-rush, exhibits a grass-like appearance in its members. The plants commonly grow in moist soil of meadows and swales, or along pond and brook margins where they may be mistaken by the non-botanist for true grasses.

The flower among members of the Rush Family is of the lily type. Indeed, rushes would be lilies if only the petals were colored and of a more delicate texture. But instead they are green or brownish, and like scale-leaves in appearance. There are the usual six stamens, just as in lilies, and the two sets of floral leaves of three each.

Many of the rushes are almost leafless, with the stems well supplied with chlorophyll to do the food making. Such species occur in sunny places, for with the lack of leaves they could not flourish unless well lighted. The wood rushes, on the other hand, have broad grass-like leaves and live in forest shade. (Figs. 98 and 99.)

Physiological Fitness of Grass-like Leaves

Plants with grass-like foliage tend to have the leaves erect. This gives an even lighting on both upper and lower surfaces of the leaf. It is interesting to note that the bits of green-colored living substance, the chloroplastids, are equally abundant throughout, but in horizontal leaf-blades as those of maple, elm, mint, and petunia the chloroplastids are chiefly near the upper surface of the leaf. It is thus seen that plants have two different ways of displaying chlorophyll to the sun's rays. Either the chlorophyll is brought to one surface of the leaf and there strongly lighted by direct rays, or else it is placed at both surfaces, each getting about half of the possible full illumination. The erect grass type of foliage is highly efficient for food making, as may be judged by the great number of grass and sedge plants in the world. On the other hand, the great majority of plant species have broad, horizontal leaves. In these facts there is given an illustration of

the principle, well recognized in human affairs, that there may be different yet equally satisfactory ways to reach the same goal.

EXAMPLES OF COLORADO GRASSES

Wild Wheat Grasses are so common that they can be easily known. It is not a simple matter to distinguish all of the different species, but it is easy to know a wheat grass at sight. All wheat grasses have the flowers grouped in a spike of numerous spikelets. The spike is straight or sometimes slightly curved, never bent over or nodding. Couch grass, so common in Europe and in the eastern part of North America, is a kind of wheat grass. Most of the wheat grasses are adapted to a life in dry soil, and hence are common in the Western States. One species occurs in loose soils and even in the sand hills of various parts of Colorado.

Wild Rye is one of the large and handsome grasses of the State. The general structure of the spike is the same as that of wheat grass, but the glumes are narrow and awn-like. The various species of wild rye may have smaller or larger spikes, but the same essential structure. The grass which is here called wild rye is not of the same genus as cultivated rye, but is much like it.

Squirrel-tail grass, or wild barley, is a common species along roads. When green, it is quite handsome and would make a fine ornamental grass did it not, when dry, break apart so easily. Barefoot boys know how the squirrel-tail works its way up their trouser legs, and one who is not bare-footed may find a piece of the broken spike boring through a stocking.

Brome Grasses of various species are handsome and graceful. At first sight they might be taken for wheat grass but the inflorescence is branched; it does not have a single continuous axis. Bromes are scattered on hillsides and streambanks. One of the species is the rattlesnake grass which grows close to the ground in broad stretches on the plains and lower foothills. It matures its seed early and dies down before the dry weather of late summer. The spikelets are somewhat suggestive of a snake's rattle and in walking through a patch of this grass there is a rustling which may for a moment give pause to one of timid heart.

Grama Grass is found on the plains in great abundance but it does not occur in bunches as do so many plains species of grass. In fact, the stems are seldom two together. The single plants may be only a few inches apart and a great number of them occur in a small area. In dry soil the plants are scarcely six or eight inches tall.

Buffalo Grass occurs in dense patches in many places where grama grass grows. Indeed these two grasses are commonly associated in what ecologists call the Short-grass Association of the plains. In coarser soils the grama grass is likely to be present without its associate. Many of the lower-altitude mountain parks bear vegetation largely of grama grass.

Three-top Grass is at its best in autumn, when most of the other vegetation is dry and brown. The plant gets its name from the flower cluster which has generally three parts. Unlike most grasses, this grass has a solid stem, just as does Indian corn. Three-top grass is often quite tall, as much as three or four feet. It is excellent for study, as the parts are large and easily identified. Relatives of the three-top are common bunch-grasses of the plains. Some are called "blue-stem".

Old-witch Grass and Red Top are closely related grasses with thin and delicate much-branched inflorescences. They grow in moist places.

Timothy is a well-known European grass grown for hay in many parts of the world. In Colorado, it becomes established along roadsides, and at the edges of aspen groves, and in meadows of the foothill and montane life zones.

Sometimes it is found in such out-of-the-way places that it might be mistaken for one of our native species. Then there is a native wild timothy in mountain meadow land, easily distinguished from the European species by its shorter and plumper spike.

Blue Grass is grown in lawns in Colorado as elsewhere. The plants have abundant horizontal underground stems which branch in all directions and send up erect stems above ground, thus forming a good sod. There are, in Colorado, thirty or more species of Poa, the genus to which blue grass belongs. Most of these are mountain, rather than plains, species. All look much alike as to their flower clusters. The commonest one found growing without cultivation is the same which is planted in lawns.

June Grass (this name is meant to apply to the genus *Koeleria*) is a frequent grass of dry situations. It is one of the few plants which can live in many climates, and so it occurs in all the different life zones.

Porcupine Grass, or as children call it, "spear grass", has very long awns which twist and untwist with changes in the humidity of the air. The awns thus bore their way into the fur of animals or the clothing of men and in this way the seeds may be carried about. Species of porcupine grass occur especially in dry soil of hillsides and rolling ground.

Chapter 13

FORESTS AND FOREST TREES

Doubtless when the word forest is spoken the reader will think of some oak grove or river bottom where he used to wander in childhood. The forest was a lonely place and the crack of a dead twig under the foot sent the blood with a start through the trembling little body. Even though it was well known that ghosts and hobgoblins live only in books, yet, if alone, it was a relief to get out of the forest and into the open places.

Few Kinds of Trees in Colorado

The cool dark shade of the beech forest is not to be found in Colorado for there are no native beeches in the State. Chestnut and hickory, ash and elm, are unknown except as shade trees planted in the cities. A dwarf mountain maple grows in canyons of the foothills but never attains any great size. Even oaks are entirely absent in most of the State and those oaks which are native to Colorado are of the "scrub" variety; only four reach the size of trees, and these trees are of small size.

It might be suggested that if Colorado is so poor in trees as this, there is hardly need for a chapter dealing with forests. But other trees are present. In the mountains, forests of spruce and pine are to be found, while along creeks there are groves of cottonwoods and poplars. In deep canyons the trees are especially tall and straight and it is possible even for those who have never been outside of the State to gain some idea of a forest. Yet, except for the conebearers, the pines, spruces, and firs, most of the trees are not large.

Different Kinds of Forests

One may distinguish various types of forest in Colorado according to topography and altitude. In the plains region there are the river-bottom forest and the pine-ridge forest. In the foothill and montane districts there are the canyon forests, hillside forests, and dry-ridge forests. At high altitudes near the bases of the snow mountains occur great areas of spruce and pine followed higher on the mountain sides by scrubby, gnarled, and dwarfed "wind timber".

Pine-ridge Forests

The pine-ridge type of forest association is seen on exposed rock ledges and river bluffs of the plains region. Most of the trees are rather small and are likely to be much gnarled because of their dry, wind-swept situation. It is seldom that these growths are of much extent, often there is merely a row of trees growing along a seam in a rock. A few kinds of trees only, can withstand the unfavorable environment. It is cold and windy in winter, hot in summer, and dry always.

The commonest tree of the ridges is the rock pine (*Pinus scopulorum*). In a few places there is also present the limber pine (*Pinus flexilis*). Although these trees are of the same species as those which grow in the foothills and mountains, yet they have a very different appearance, being much more crooked. In fact they may remind one of the Japanese pine trees pictured on screens and fans.

Along with the pines there are hackberry trees, also distorted and with very rough and warty bark. The hackberry belongs to the elm family and the leaf resembles that of the elm but the berry-like fruits, as well as the more roughened bark and less graceful branching, show that the trees are not really elms. A few low cedars may grow with the hackberries and pines and often there are such shrubs as mountain mahogany, bird cherry, and wild currants.

Pine-ridge forests are to be seen in western Nebraska as well as eastern Colorado, and may be considered as eastward extensions of the foothill vegetation. From some of the railways across the plains it is possible to get, now and then, a passing glimpse of pines and cedars on the distant bluffs.

Cottonwoods

Along a river bottom, it sometimes occurs that a considerable extent of open land is kept well watered by seepage from the stream. In such a place a dense growth of trees may develop and there may be underbrush as well. The trees are chiefly poplars and willows, with a few box-elders and alders. Three kinds of poplars occur along streams in northern Colorado, east of the Divide: the broadleaf cottonwood (*Populus sargentii*), the narrowleaf cottonwood (*Populus angustifolia*), and the lanceleaf cotton-

FIG. 100. Broad-leaf Cottonwood. A common tree along streams of the plains region. Known to botanists as *Populus sargentii.*

wood (*Populus acuminata*). The last two trees resemble the ordinary cottonwood in form and appearance but the leaves are much narrower. In fact the narrowleaf cottonwood may be mistaken for a willow by those who do not observe closely. The broadleaf cottonwood is the common species of the plains region. Many smaller streams have no narrowleaf cottonwoods along their course in the plains country, although these trees are abundant in canyons. In southern Colorado, the common broad-leaf cottonwood is replaced by Wislezeni's cottonwood, which species is also reported from the Western Slope. The quaking aspen, so well known in the mountains, is also a poplar (*Populus tremuloides*). It grows in the montane zone and in the foothills but does not get down upon the plains.

The wood of cottonwoods is light and not strong, but is suitable for burning in stoves, and can be used for fences and the like. The trees are quick growers, sometimes increasing an inch or two inches in diameter during a single season. Ranchmen living near streams in the plains region might well grow the trees for fire wood and for fence posts or rails.

WILLOWS

Various kinds of willows are found on river bottoms along the streams of the plains and foothills. The different species are difficult for the amateur to distinguish and may well be left to the professional botanist for study. It is, however, easy enough to separate the very narrow-leaved forms from those with more ovate leaves, and to learn which ones come into blossom before the leaves appear and which ones produce their catkins after the unfolding of the leaf-buds.

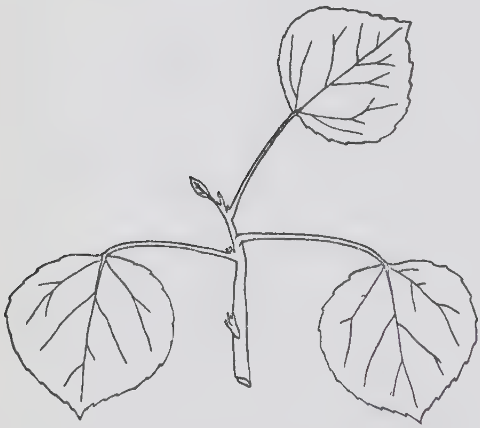
DIFFERENCES BETWEEN WILLOWS AND COTTONWOODS

Willows and poplars belong to the same family and have much in common; but the bark of poplars, especially that of the younger branches, is whitish and smooth, while that of willows is gray or brown and usually rather rough. Both genera have the staminate and pistillate flowers on separate trees. In willows, the catkins, which are, of course, the flower clusters, stand erect while those of poplars are pendant. The pollen of the poplars is carried by the wind to the flowers of pistillate trees, while bees and other insects are the agents of pollination for willows. Since the poplars

depend upon wind to carry their pollen, they must produce this before the leaves appear, else most of it would fall on the leaves and have no chance to bring about fertilization and seed ripening. As for willows, it is of no importance at what time the flowers come, because bees will seek out the flowers in order to get the nectar and will fly from tree to tree and carry the pollen grains.

Seeds Distributed by Wind

Cottonwoods and willows spring up readily and in great numbers in moist soil. Their seeds have been distributed by the



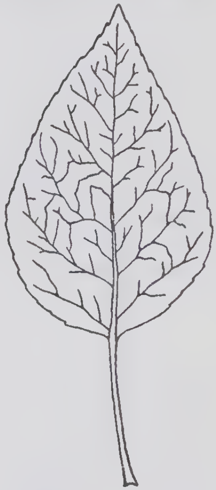


Fig. 101. Aspen (at left). Especially abundant in the montane region. One of the most widely distributed trees in North America.

Fig. 102. Balsam Poplar (at right). Not at all common in Colorado; it grows in seepage areas. Often called "Balm-of-Gilead".

wind which takes hold easily of the light cottony hairs that envelop them. Where cottonwoods are planted as shade trees, the ground under them sometimes is covered with this snow-like material to a depth of an inch or more. The cotton becomes attached to clothing and even invades houses. If the pistillate trees, or cotton-bearers, can be cut down, thus leaving only the staminate trees, these difficulties are avoided. Only staminate poplars should be planted.

Oak Thicket and Scrub

An interesting plant association is that of the scrub oaks. These trees and shrubs of foothills and mesas extend into the

canyons and form large clumps on hillsides and canyon slopes. In the neighborhood of Colorado Springs there are many oaks, some very small, some of larger size, but few real trees. They produce acorns, just as any other oaks do, though these may be few and hard to find. Traveling by rail between Denver and Colorado Springs one may see from the car window the oaks of the mesa ridges sometimes making small circular patches, sometimes extending in serpentine curves along a hillside. At Denver, there are no native oaks, but as the train goes southward, oaks are soon in sight and are found here and there the whole distance south through the State. To the north of Denver there are not any at all, and many a Colorado boy or girl who has lived at Denver or to the north has never seen an oak tree, unless perhaps in some park or private estate. In the western part of the State, oaks extend to the Wyoming boundary.

TREES OF CANYON-SIDES

If a traveler follows up one of the rivers or creeks from the plains into the mountains he soon leaves behind the broadleaf cottonwood, but the other poplars continue to be seen here and there. Farther along, where the stream has cut its way as a narrow canyon with steep sloping sides, the rock pines (*Pinus scopulorum*) and Douglas spruces (*Pseudotsuga mucronata*) work their way down close to the water's edge. Still higher, at upper altitudes, the pines become largely replaced by the Engelmann spruce, with here and there beautiful examples of the blue spruce (*Picea parryana*), the Colorado State tree.

THE PINES

Some people imagine that all cone-bearing trees are pines, but this is quite erroneous. It is true that all of the cone-bearers of Colorado belong to the pine "family", but fir and spruce are not properly "pines". It is easy to distinguish the true pines from these other members of the pine family, because pines have the leaves, or needles, in bunches of two, three, or more together, while spruces and firs have the leaves separate, not in groups. The leaves of the rock pine are in fasicles of two or three. They are quite long, often four inches or more. The limber pine and bristle-cone pine have five leaves in a cluster, the lodgepole pine has the leaves in twos, as has also the pinyon pine. The last

named, possesses very short needles, about an inch in length. Pines are distinguished from firs and spruces not only by the leaves but also by their hard, woody cones, which take two or more years to mature. (Figs. 103 and 104b.)

The different kinds of pine trees in Colorado have, for the most part, special situations for their growth. On the mesas and lower foothills are the rock pines, often widely scattered but sometimes in beautiful groves. Then in the southern and western parts of the State there are, in addition, pinyon pines growing in slightly warmer and drier places than those occupied by the rock

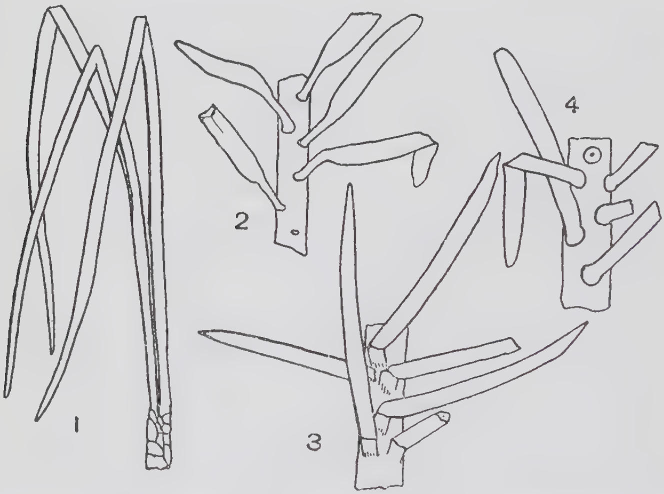


FIG. 103. Leaves of Coniferous Trees. *1*. Pine (Pinus); *2*. Douglas Spruce, or Douglas Fir (Pseudotsuga); *3*. Spruce (Picea); *4*. Fir, or Balsam (Abies).

pine. Lodgepole, bristle-cone, and limber pine belong farther up in the mountain country. Limber pines are seen especially in wind-swept situations. Lodgepoles grow abundantly on north slopes of the upper foothill districts where they spring up quickly after a fire and soon reforest the areas of burnt ground. In the montane zone (8,000 to 10,000 feet altitude) lodgepole pines may be common in all situations. They often extend as far even as timberline.

A word about the pinyon nut may be of interest. This so-called "nut" is for sale at fruit stands in Denver and elsewhere.

FIG. 104a. Cones of Pines. At top, the pinyon pine; left, limber pine; right, rock pine.

FIG. 104b. Cones and Leaves. At the left, Douglas spruce; middle, Engelmann spruce; right, sub-alpine fir.

It is merely the seed of the pinyon pine. All pine trees produce seeds in their cones but in most of them the seeds are small and light, each bearing a thin, expanded margin which makes the seed easily blown by the wind. The pinyon pine, however, has a heavy seed nearly a half-inch long. There is a thick seed coat enclosing the meaty part, within which at the very center lies the embryo, or young plant. Pinyon nuts have a pleasant flavor, but to remove the seed coat is so troublesome that they are not in great demand.

THE DOUGLAS SPRUCE, OR DOUGLAS FIR

Christmas trees in Colorado are Douglas spruces. These trees grow in narrow canyons and on steep slopes throughout the foothill region of the State. Generally they are symmetrical in form, of feathery appearance, and bear a great many cones, which are scattered even to the lower branches. These cones are distinguished from those of true spruces and of firs by the three-toothed bract which projects from each of the true cone scales. The needles of the Douglas spruce (known also as Douglas fir) are soft and flexible and it is on this account that the trees are used at Christmas time. The true spruces, with their sharp-pointed needles would be unpleasant to handle for decoration, and since the leaves drop off soon after the trees are cut, spruces would be quite unsatisfactory. The fir, or balsam, is the Christmas tree in most parts of the world. Our firs would do very well but they are not so numerous or so easily obtained as Douglas spruces.

THE TRUE SPRUCES OF COLORADO

Blue spruce and Engelmann spruce, both of them true spruces, resemble the Douglas spruce in having short leaves, or needles, but the leaves are jointed near the base and the basal part is brownish and woody. The leaves are also stiff and sharp pointed, especially those of the blue spruce. With these differences between the Douglas spruce and the true spruces it is not hard to tell them apart, and yet there are very few residents of the Rocky Mountain region who know them. The wood of the Douglas spruce is red and rather hard, that of the true spruces is white in color and nearly as soft as white pine.

Many specimens of the blue spruce show a silvery or grayish tinge, and are then called "silver spruce". It seems that this

appearance is an individual peculiarity of certain trees and does not depend on soil, moisture, or exposure. Certain trees have silvery foliage, differing from the more common green, just as some people have hazel eyes, being thus different from the usual run of brown-eyed and blue-eyed folk.

True Firs

The true firs are by no means so common as the spruces. They grow only in rather high altitudes and occur here and there mixed with spruces and pines. When cones are present on the trees, the firs may be distinguished from spruces because their cones stand erect and candle-like on the branches, instead of hanging pendant. The trees grow to a large size where conditions are favorable. The bark is smooth and very light colored. Branching is symmetrical. Firs are handsome trees; the white fir which occurs in the Pikes Peak region and southward and westward is one of the most beautiful members of the pine family.

Cedars and Junipers

Of evergreen trees in Colorado besides pines, spruces, and firs, which are all members of the pine family, there are the cedars, which belong to the juniper family. Many different trees in various parts of the world are known as cedars. Most of them agree in having short, flat, overlapping scale-like leaves. In the Rocky Mountain region there are no large species, but some individuals of the mountain cedar (*Sabina scopulorum*) are beautifully symmetrical, and make very suitable trees to plant at the entrances of public buildings. Besides these more favored individuals there are stunted or gnarled forms growing in dry rocky gulches or on exposed bluffs. Such trees have rough, shaggy bark and irregular branches.

Closely related to the cedars are the junipers of low habit—in fact nothing more than shrubs. They have sharp-pointed short leaves and berry-like fruits, "juniper berries", of aromatic odor and taste. The common Siberian juniper (*Juniperus siberica*) of the Rocky Mountains is now frequently planted in parks. It is interesting to note that young cedars agree with junipers in having pointed leaves, but as cedars grow older the later leaves are blunt and do not stand out from the branch but overlap one another. Thus the similarity so apparent in the young forms

disappears in adult life. When cedar trees are injured by being brushed against frequently, or by disease, the affected branches often produce the sharp-pointed "juvenile" type of leaf, so much like the adult leaves of the juniper.

THE ASPEN

In mountain districts of Colorado nearly all of the trees are pines, spruces, firs, and Douglas spruces. There are, however, in places some good groves of quaking aspens (*Populus tremuloides*) and scattered willows here and there among the evergreens. The aspens often spring up in burned-over land if the soil receives some seepage. They do not grow well in dry, stony ground. These trees are well known to people of the Northern States, being often called "white poplar" because of the chalky whiteness of the trunks. In autumn, the leaves turn yellow and the aspen groves on a mountain side can be seen from a great distance as golden patches amid the general forest green of pine and spruce.

THE VALUE OF FORESTS

The value of forests is not merely in the lumber which may be cut from them. In all mountain regions, forests are needed for protection. A protection forest saves the soil from being washed away, it prevents too rapid melting of snow and consequent floods, and it provides steady stream-flow for irrigation in the lowlands. Without forests on our hills and mountains there could be little agriculture in Colorado. Wherever mountain forests are dense the soil is deep and, retaining moisture for a long time, furnishes the streams with a constant supply of water doled out little by little through the season.

Large areas in the foothills and in the mountains of Colorado can never be used for agriculture or for mining. If they are to be made productive they must be allowed to grow up with trees. Fires must be kept down and the forests protected from injury of all kinds. Many of the partly denuded hillsides can be clothed with timber in thirty or forty years. The time is coming soon when the value of timber will be even greater than it is now. It will pay individuals and corporations to grow trees for the market. Despite the opening up of new coal mines and the employment of brick, stone, and metal for building purposes the use of wood is on the increase.

Our native trees may be a source of wealth. In Colorado the Douglas spruce is common, growing in canyon bottoms and on moist hillsides. With proper protection of the young trees and the carrying-out of a scientific forest policy this species may furnish in future much valuable timber. The rock pine, or "western yellow pine", and the Engelmann spruce will become important. Even the lodgepole pine can be made useful for many purposes when proper methods of seasoning are employed and if suitable treatment is used to prevent decay. The pinyon pine makes excellent charcoal and is a good fuel.

Forests are valuable places for recreation. Aside from their importance for protection of watersheds and as a source of timber for mines and for building purposes, they form a great asset in attracting tourists to the State. The forests of the mountains serve as recreation grounds which are being ever more widely used.

NATIONAL FORESTS

The National Forest Service has recognized the importance of forests in Colorado, and has given much attention to their scientific management. About one-fifth of the entire State is within the boundaries of national forests. While, at present, the amount of possible timber cutting is not great, it may be expected to increase from year to year, especially if forest fires can be prevented.

INJURY DUE TO FOREST FIRES

In the montane life zone where forest was burned 30 to 60 years ago there is now often a close stand of lodgepole pines. These trees, along with aspens, sometimes get started quickly after a fire, if the fire has not burned so deeply into the soil as to leave no place for seedlings to grow. The cones of the lodgepole pine are caused to open by the heat, and they scatter their seed upon the ground. If the original forest had even a few lodgepoles, a good sprinkling of these trees will come up in the "second growth". The pines eventually crowd out the aspens, which are unable to endure much shade. The lodgepole forest is likely to give way, in time, to a mixture of pines if on dry ground, or to spruce and fir in moister situations. But the process is a slow one, and a complete return to the original type of forest takes many

centuries. The lodgepole forests, are more permanent than aspen woods, yet, as stated, they do not form the final forest-stage.

It is seldom that a burned area is so soon reforested as suggested in the previous paragraph. This is because the forest fire destroys, not only the trees and other vegetation, but also the soil into which it eats its way, burning the roots which hold the mineral particles together, permitting the soil to be washed away

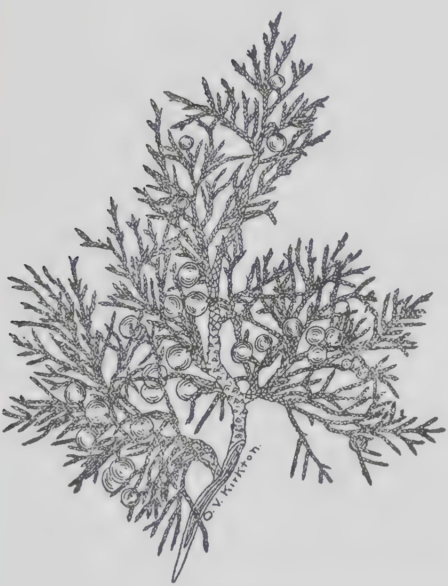


FIG. 105. Rocky Mountain Red Cedar (at left). One of the native Colorado trees which is frequently planted. These cedars are often of very symmetrical form, tall and narrow.

FIG. 106. Siberian Juniper (at right). A prostrate evergreen shrub often planted in parks and private grounds. Native in the mountains of Colorado nearly up to timberline.

by rain so that, in steep-sloped areas, there may be no forest growth again for centuries.

Most fires are started by campers and motorists who either make no serious effort to put out their camp fires, or who build fires against large logs where the complete extinguishment of the fire is difficult. Usually the offenders have left the vicinity before the fire is discovered, and they may not know how the

FIG. 107a. Mountain Maple, a small tree or large shrub of foothill canyons through-out the State. Useful for ornamental planting.

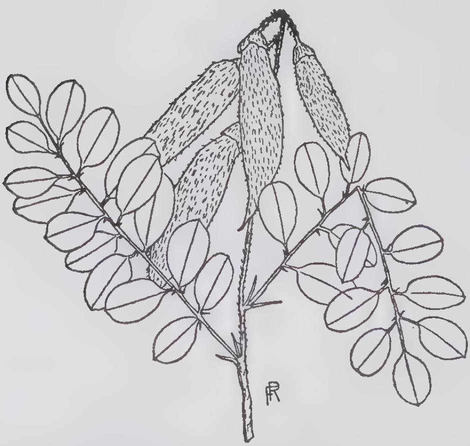


FIG. 107b. Pink-flowered Locust. Small tree along streams in Southern Colorado. Valuable as an ornamental tree for parks and private grounds.

beautiful landscape of yesterday, which they themselves so much enjoyed, has today been transformed to a scene of desolation.

It requires a long time to produce soil to take the place of that which has been destroyed; even herbaceous plants may be scarce for a period after a severe fire. But these plants eventually come in and occupy all available ground. Their roots hold whatever soil was already there, and the stems catch and keep other soil which may be washed from higher ground or blown in by the wind. Soils are formed chiefly by weathering of rock; the water which gets into cracks alternately freezes and thaws, and the expansion of water when it freezes serves to make the cracks deeper and to produce a splitting off of rock fragments which are the beginnings of soil. Lichens growing on rocks are also an agency of soil formation; they hold water, keeping the rocks wet, thus favoring injury of the rocks by freezing. They add organic matter to the soil, as bits of the lichen become mixed with rock particles. The soil can now support the growth of sedges and grasses. With further production and accumulation of soil, shrubs and trees may again become established. But how long it takes! A forest fire, in a single week, may destroy that which can not be replaced in the time of a dozen generations of men.

DIFFERENT KINDS OF FOREST IN COLORADO

An understanding of the forests of Colorado can best be reached by a consideration of the various types or associations. Those of dry situations are called xerophytic, those provided with a moderate amount of moisture are known as mesophytic. In the accompanying table the chief points of interest are brought together in form for easy comparison.

FORESTS OF COLORADO

Designation and Moisture Relation	Life Zone	Principal Trees
River-bottom Forest; mesophytic	Plains	Broadleaf Cottonwoods Willows Pink Locust Box-elder
Drier Foothill and Pine-ridge Forest; xerophytic	Plains and Foothill	Cedars Pinyon Pine Rock Pine Oaks
True Foothill Forest; xerophytic	Foothill	Rock Pine
Canyon Forest; mesophytic	Foothill and Montane	Narrowleaf Cottonwood Willows Alder and Birch Douglas Spruce, true Spruces Thornapples Plums and Cherries
Aspen Forest; mesophytic	Montane and Foothill	Quaking Aspen
Montane Moist Forest: mesophytic	Montane	Englemann Spruce Douglas Spruce Pines
Montane Dry Forest; xerophytic	Montane	Lodgepole Pine Other pines
Sub-alpine Moist Forest; mesophytic	Sub-alpine	Engelmann Spruce Firs
Sub-alpine Dry Forest; xerophytic	Sub-alpine	Limber Pine Bristle-cone Pine Lodgepole Pine
Sub-alpine Wind Timber; xero-mesophytic	Sub-alpine	Engelmann Spruce Fir Pines

Genera and Species of Native Trees

The total number of species of native Colorado trees is not quite fifty, distributed in eighteen or nineteen genera. Some of these genera have two or more species in the State, others have a single one. Practically all of the genera occur both east and west of the Continental Divide, although some of the individual species are restricted to one side or the other. Certain facts are shown in the accompanying table. In examining the table it should be kept in mind that trees only are listed while the species which

form shrubby growths are not included. Thus, in addition to the six tree-species of willow there are close to twenty shrubs; shrubs occur also in the genera Betula, Quercus, and Prunus. (Readers are referred for additional information to Appendix I.)

GENERA OF NATIVE TREES IN COLORADO

Name of Genus, with English Name	Number of Tree Species	Name of Genus, with English Name	Number of Tree Species
Pinus; pine	5	Quercus; oak	4
Picea; spruce	2	Celtis; hackberry	1
Pseudotsuga; Douglas spruce	1	Cercocarpus; mountain mahogany	1
Abies; fir	2	Amelanchier; Juneberry or service-berry	1
Sabina; cedar	3	Crataegus; thornapple or hawthorn	6
Populus; poplar or cottonwood	6	Prunus; plum and cherry	3
Salix; willow	6	Robinia; locust	1
Betula; birch	2	Acer; maple and box-elder	2
Alnus; alder	1	Fraxinus; ash	2
			49

FORESTS OF THE ANCIENT PAST

In former geologic times, the forests of Colorado were not so restricted in the number of species as at present; or at any rate during certain times many trees were here which now do not grow without cultivation within the confines of the State. At various places, fossil remains of tree leaves, some of them beautifully preserved, tell very clearly the history of our forests.

It is certain from a study of these fossil remains, that for hundreds of thousands of years the general aspect of vegetation in the plains, foothill, and montane zones has been much the same as now. There have been upon the hills all this time the pines, spruces, cedars, and oaks; while cottonwoods, birches, alders, hackberries, thornapples, maples, sumacs, and Juneberries grew in the canyons during prehistoric times just as they do now. Some differences, however, have been noted. The oaks and cottonwoods, although very similar for long periods of time, are not exactly the same as those which grew here a million years ago. Certain evolutionary changes have taken place in the shapes of leaves and in their sizes.

The chief changes in the forest flora have been due to modifications in climate; there is no doubt that some millions of years back, what we now know as Colorado was less arid than at pres-

ent. The moister climate permitted the growth of many plants which can not now live here except with irrigation. This is known by the occurrence in the rocks of fossils showing the existence of mulberry, elm, beech, redbud, and walnut, now no longer wild in the State, although they will grow here if planted and cared for. At a still more remote time the climate was not only more humid but also warmer than now, as is evidenced by fossil leaves of figs, of palms, and of cycads. At Florissant, Colorado both leaves and fruit of fig occur in fossil condition. Here also are petrified stumps of redwood; yet this genus is now confined to the Pacific Coast States.

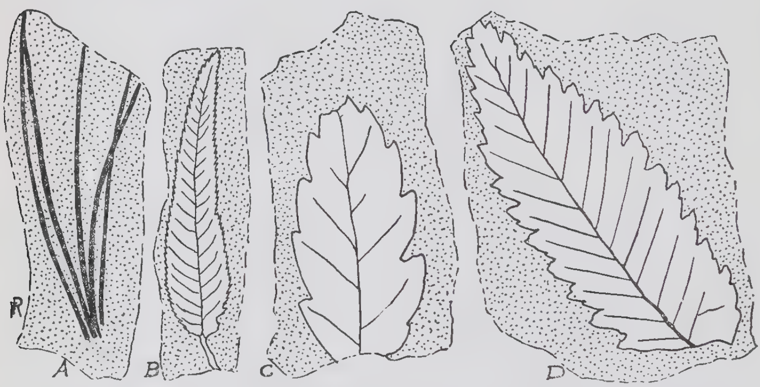


FIG. 108. Fossil Leaves from the Miocene Shales of Florissant, Colorado. Probably five or ten millions of years old. *A*. Needles of Pine; *B*. Willow leaf; *C*. Leaf of a kind of Oak, almost indistinguishable from some of the present-day scrub oaks of the State; *D*. Elm Leaf. The Elm no longer grows in Colorado without cultivation. (Figures one-half natural size.)

GEOLOGIC ERAS, PERIODS, AND EPOCHS

An understanding of the former plant life of Colorado calls for reference to a geologic time table. In such a table there are listed the eras, periods, and epochs of geologic history as determined by a study of the rocks which form the crust of the earth. Such a table, simplified as far as possible, is given on page 217. The Paleozoic era shown at the bottom of the table, was preceded by other eras but the rocks of these earlier times contain few organic remains; such remains as do exist belong only to very simple plants and animals. In the fourth column, only those geologic formations of Colorado are listed which have furnished plant fossils. Most of the geologic periods are represented

by rocks somewhere in the State; some as yet have not been identified here although well known elsewhere.

GEOLOGIC TIME TABLE

The eras and periods before the Paleozoic have been omitted, since probably few plants of more than microscopic size existed in those times. In the last column only those formations are listed which are known to contain plant remains.

Eras	Periods	Epochs	Formations in Colorado Having Plant Remains
	Quaternary	Recent, or Post-glacial Pleistocene	
Cenozoic	Tertiary	Pliocene	
		Miocene	Florissant
		Oligocene	
		Eocene	Wasatch, Denver, Raton, Dawson, Green River
Mesozoic	Cretaceous	Upper	Laramie, Foxhills, Trinidad, Pierre, Mesa Verde, Vermejo, Dakota
		Lower	Morrison, McElmo (?)
	Jurassic		
	Triassic		(In Southwestern Colorado)
Paleozoic	Permian		(In South Park, near Fairplay; possibly Permo-Carboniferous, rather than Permian)
	Pennsylvanian		Glen Eyrie
	Mississippian		
	Devonian		
	Silurian		
	Ordovician		
	Cambrian		

How Old are the Fossil-bearing Rocks?

Readers will want to know the age in years of the geologic epochs, but this can not be given with certainty. The Miocene epoch of the Tertiary has been estimated as existing one million years ago. Recently, however, the view has developed that the time should be greatly lengthened, perhaps to ten million years.

Let the reader examine the geologic time table again and see what this means as to the age of earlier rocks. If the estimates for the Miocene are anywhere near correct, then the Eocene, or beginning of the Tertiary, must date back to an almost inconceivable antiquity. What then of the fossils in the Cretaceous? How long ago did the trees flourish whose remains are found in rocks of Permian or Pennsylvanian age?

LOCALITIES FOR FOSSIL PLANTS

Places within the State where fossil plants may be collected are numerous. At not all of these, however, are the plants well preserved and possible of identification. The following localities have already furnished many specimens: Florissant, Golden, Morrison, Marshall, Erie, Kiowa, Sedalia, Manitou, Fairplay, Florence, Trinidad, Rockvale, Meeker, Roan Mountains.

FORESTS OF PALEOZOIC TIMES

The few Paleozoic plant fossils thus far discovered in Colorado are from the region of Manitou and from South Park near Fairplay. These remains are of scale trees (or tree clubmosses), of tree ferns, and of Cordaites, one of the ancestors of present-day cone-bearing trees. The geologist Schuchert, in speaking of forests in late Paleozoic times, says:

> . . . Their most striking representatives in number and size are the scale trees, a sort of evergreen having comparatively small needle-like leaves; some of these trees grew to over 100 feet in height, and to a diameter ranging up to six feet . . . These floras also included many fern-like forms, both delicate and hardy, some of which were climbing in habit, while others grew into majestic trees; most of them bore seeds, but some were spore-bearing and therefore true ferns.
>
> In general, these forests must have reared their tops higher than 40 feet. They were of rapid growth and of soft and even spongy wood . . . Shades of green were the dominant color. . . .
>
> —Text Book of Geology, part II, p. 375. 1924.

MESOZOIC FORESTS

With the advent of the Cretaceous Period the forests of Colorado came to have trees more like those of the present day. From the lowermost part of the Cretaceous, comparatively few species have been secured; some of these are closely akin to present-day trees. Beginning with the Dakota Formation, there are many

genera identical with those now living here or in other parts of the world, although the species are in no case quite the same. At Morrison, near Denver, the specimens described include figs, oaks, laurel, and magnolia; besides these there are other trees, shrubs, and herbaceous plants, many genera of which are now extinct.

The later Cretaceous floras have more trees and other plants of distinctly modern type. Figs, oaks, laurels, and magnolias continue and there are, in addition, palmetto, redwood, haw, cinnamon, dogwood, thornapple, hickory, box-elder, willow, and poplar. It is evident from this that the climate must have been less arid than at present and also somewhat warmer. Many of these trees no longer grow in Colorado, although they are found in our Southeastern States.

CENOZOIC FORESTS

The forests that existed at the dawn of Tertiary times, namely those of the Eocene epoch, continued to have many of the earlier genera, but the species were different. Walnut, maple, plane tree, buckthorn, elm, chestnut, alder, and birch also were present.

In the Miocene* shales of Florissant, Colorado, described by Professor Theodore D. A. Cockerell, there are wonderfully perfect fossils which tell of a flora rich in trees and shrubs nearly all the genera of which have persisted down through the millions of years to the present time. In some cases the species themselves can hardly be distinguished from those now living in the State. This is especially true of certain poplars, thornapples, and oaks. A complete list of the trees which grew along the shores of the lakes near the present town of Florissant would include probably one hundred species. It will suffice to give the English names of the more characteristic and well-known genera; pine, redwood, incense-cedar, willow, poplar, walnut, alder, birch, ironwood, chestnut, oak, beech, elm, mulberry, hackberry, fig, sweet gum, Juneberry, thornapple, mountain-ash, acacia, locust, tree-of-heaven, smoke tree, holly, maple, buckthorn, basswood, ash. Here again, the list suggests greater rainfall than that of Colorado at present. But the most interesting feature of the flora of the Florissant lake beds is its exceedingly modern aspect. If a

*By some authorities considered as Oligocene.

present-day botanist, say from New York, could be blindfolded and put back into a Miocene forest of Colorado, he would see, when the handkerchief was removed, a number of species that he did not know, but there would be nothing bizarre or strange in the general aspect of the forest. There is little likelihood that it would occur to him that the time was other than the present Year of Our Lord.

Through such long ages do plant types remain with little change!

Chapter 14

THE ARCHITECTURE OF PLANTS

The usual parts of plants, the roots, stems, and leaves, are easily recognized as definite and distinct members of the plant body. Underground stems, however, such as the rhizomes of blue grass and Solomon's seal, may be mistaken for roots, but they bear scale-leaves and have a jointed structure like that of ordinary stems. The bulb of an onion and the tuber of a potato also are shoots rather than roots, although their true nature is not at once quite apparent. Flowers, fruits, and seeds are known to be, in their texture and make-up, different from ordinary vegetative parts.

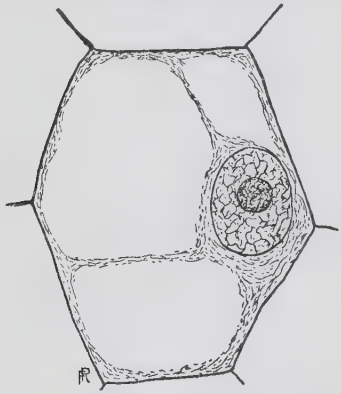
The general appearance, or growth-form of a plant is affected by ecological factors, as sunshine, wind, moisture, and the quality of the soil. The stunting influence of drought and the all-around bad results of too much shade are well known. Among trees, the modifications in form due to pruning and wind-injury are often apparent, as also those caused by unusual shading or close crowding. Trees growing alone, tend to spread out; in a dense forest they grow tall and slender. Some trees, however, are always tall wherever they grow. A lombardy poplar is as slender on an open lawn as in a dense grove. It is like a dignified man, who is no more able to unbend on a camping trip than in his city office,—always the same, no matter what the conditions. Spruce and balsam-fir are much alike in all places; they change but slightly whether in the dense forest or in a clearing. But crowding and shutting out of light will cause many trees to grow in height rather than in thickness of trunk. Side branches fall off because of lack of light; the strength which would go into them is put forth in upward growth. Pines, elms, and maples are rather easily modified by external factors. But such changes do not affect their true inner structure.

Internal Structure of Plants; Early Studies

Two herbs or two shrubs may look much alike from the outside, even if the arrangement of materials within is not the same. Such plants may be compared with two buildings of the same general appearance but with different placing of pillars, gird-

ers, and walls. One stem has its strengthening materials in compact masses, another has them scattered about with wide interspaces.

Something of the internal structure of plants was known to the ancients. Theophrastus, the "father of botany" who wrote in the third century before Christ, knew about pith, wood, bark, fibers, and other parts of stems. He could not, however, go far in the study of the exact make-up of plants because he had no magnifying lenses with which to learn the finer details of what he



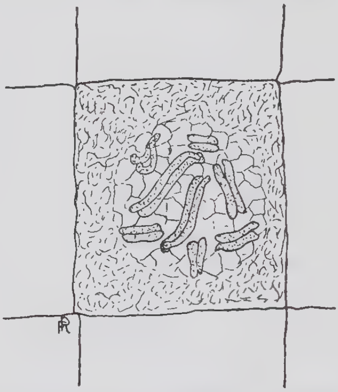


FIG. 109. Typical Plant Cell (at left). Various parts are shown: the cell-wall, the cytoplasm, the spherical nucleus and its contained nucleolus, and the spaces (vacuoles) within the cell which are filled with water, or sap. (Magnified 500 times.)

FIG. 110. Young Cell; diagrammatic drawing (at right). This drawing is introduced to show the chromosomes within the nucleus. They are especially prominent at certain stages in the life of a cell. This particular cell is shown with eight pairs of chromosomes. (Magnified 1000 times.)

saw. It was not until the development of the compound microscope that plant anatomy, the study of the internal structure of plants, could become a science. About the year 1667, Robert Hooke, an Englishman, first used a microscope in the study of plant substance. He looked at a bit of cork and found it to be made of little boxes resembling the cells of honey-comb. Other students began to study the structure of various parts of plants, and established well the science of plant anatomy which many teachers believe to be a necessary foundation for any real botany.

PLANT CELLS

It is to plant cells that attention must be turned if the architecture of plants is to be understood. All of the beams, walls,

covering, strengthening materials, pipes, and other structural features of the plant are made of cells. These cells differ in size, shape, and strength, and in their permeability to water.

Probably the easiest way to get some idea of plant architecture is to examine a thin slice of elder pith or other similar plant material under the microscope. If this be done, the honey-comb-like structure may be seen, already mentioned as found in cork. The cells composing the entire mass of pith are eight- or twelve- or many-sided boxes. There is not a geometrically perfect arrangement of the cells, for some are larger and some smaller, but the appearance is not greatly different from that of a honey-comb. It would take at least a hundred elder pith cells placed in a row to extend across a cell of honey-comb.

A thin slice of elder leaf or wood or bark, or a thin section from any plant, will agree in some ways with that taken from the elder pith. A bit of the pulp may be scraped from an apple or potato or a carrot and examined in a drop of water with the microscope. In any of these there will be cells as before. They may be of different sizes and forms, and the walls be of different thicknesses, but in all cases they can be likened to boxes.

THE LIVING SUBSTANCE, PROTOPLASM

These boxes are empty when examined, but during life they contain the living substance, or protoplasm, which has formed the cell-walls and is responsible for all vital processes in the plant. Since this living material is colorless and transparent, it is not likely to be seen unless special means be taken to make it visible. It can be rendered visible by treating the specimen with some dye which will give color to the otherwise transparent substance.

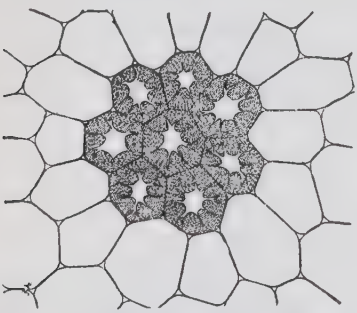
If a thin section of some plant-part be treated with iodine, the protoplasm becomes colored a yellowish brown, while the cell-walls are hardly affected. The protoplasm under high powers of the microscope, shows a somewhat frothy appearance, resembling snow pudding or beaten white of egg. Sometimes it seems to be composed of little granules and short threads, floating in a thin transparent jelly.

The skin peeled off from one of the scales of an onion bulb, or from the under surface of a petunia leaf, when mounted in water makes a very good object for study of protoplasm. The

specimen may be stained with iodine or with some anilin dye. The hairs which grow on the stamens of spiderwort, or those on the leaf-stalks of tomato or of Chinese primrose, are still more interesting. In these hairs, the protoplasm will remain alive for a considerable time, and its activities can be watched.

STREAMING MOVEMENTS OF PROTOPLASM

Living cells in good microscopic preparations show the granules and particles of the protoplasm in motion. Slender streams pass slowly around the cell just inside of the cell-wall or they cut across diagonally, now moving rapidly, now almost halting, or even coming to a full stop. For a time, the streaming movements may not be apparent at all. Then they begin again, perhaps showing a different direction. It is fascinating to watch these



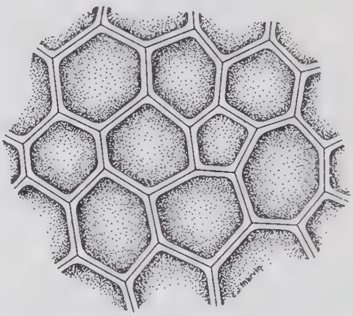


FIG. 111. Cells from Fruit of Pear (at left). Stone cells in the center, surrounded by soft tissue. (Magnified 500 times.)
FIG. 112. Cells from Pith (at right). (Magnified 300 times.)

simple manifestations of vital activity and to realize that here are life movements reduced to the lowest terms.

THE CELL NUCLEUS

Every typical cell has a denser part of the living substance known as the nucleus which was first seen in 1831 by the famous British botanist Robert Brown. The nucleus may be a minute sphere, or in some cases it may have the form of a football or a doorknob. At first sight, it appears to be merely a somewhat compact part of the protoplasm, but it has been found to have a very definite structure of its own. Surrounding the nucleus there is an extremely delicate membrane which separates it from the cytoplasm, as the rest of the protoplasm is called. In

the body of the nucleus itself, there is a very wonderful substance known as chromatin. This chromatin contains the particles of matter which control the activity and life of the cell. Every cell has its nucleus, each nucleus contains its essential chromatin. The term chromatin—from the Greek "chrom", meaning color—was given because of the ease with which this material may be colored or stained with dyes. (Figs. 109 and 110.)

THE CHROMOSOMES; HEREDITY

At certain times in the history of any cell the chromatin of the nucleus exists as definite threads or rods known as chromosomes, literally, "color bodies". The chromosomes are of the same number in every cell of a given plant, but different numbers exist in various plant species. Thus the onion has eight pairs of these small bodies, evening-primrose seven pairs, the lily 12 pairs, nightshade 36 pairs. The chromosomes have an individuality; only those of a pair are alike. Differences exist in size and shape. Animals also have chromosomes in different numbers; thread worm, two pairs; a certain ape, 24 pairs; man, 24 pairs; horse, 30 pairs; certain crayfishes, 100 pairs. The number of chromosomes in the cells of a plant or animal can not be taken as an index of the creature's complexity. Here, as often, quality rather than quantity is more important.

In recent years, biologists have built up "the chromosome theory of heredity" which makes of the chromosomes very marvellous structures indeed. According to this theory, which now seems thoroughly established, the chromosomes contain, or are largely made up of, the determiners, or factors, of heredity. One anemone plant has cream-colored flowers and another has red flowers, because of chromosome differences. The red oak grows tall but the native oaks of Colorado reach only the height of shrubs, because of different inheritance units in their chromosomes. The various hereditary features which distinguish individuals or species from one another result from chromosomal structure. In some cases the particular chromosome which holds the determiner for a definite quality or feature can be recognized under the microscope.

The extreme complexity of the living substance, and especially of the chromosomes, can not be appreciated unless the existence

of the inheritance factors be understood. They have their part in the architecture of the chromosomes, and therefore in the structure of the cell and of all parts of the plant. Protoplasm is not merely a complex chemical compound, or even a mixture of such compounds; it has a definite organization of great delicacy. The hope expressed of producing life by stirring up various ingredients in a glass test-tube need hardly be entertained. The more there is known about the microscopic structure of living substance, the greater is the wonder at its intricacy of detail.

CELL-WALLS

Certain features of plant architecture are not so difficult to present in simple form as those which concern the protoplasm.

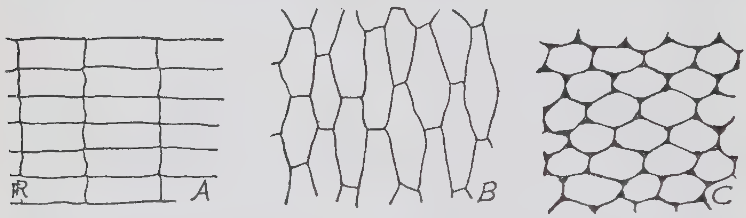


FIG. 113. Different kinds of Plant Cells. *A*. Cork; *B*. Leaf Epidermis; *C*. Thick-angled Cells. (Cork and thick-angled cells magnified 500 times; epidermis enlarged 300 times.)

The shapes and sizes of cells may be studied with moderate powers of the microscope. Differences in cell-wall thickness and in composition are easily recognized. There is so much interest connected with cell-walls that their consideration may well furnish the material for the rest of the present chapter. Let it not be forgotten, however, that the cell-walls are formed by the activity of the protoplasm, much as an oyster shell is produced by the living oyster. Cell-walls are perhaps not to be thought of as truly alive. Neither are they quite so lifeless as the oyster shell.

The neglect of the living substance in the remainder of the chapter may be justified on the ground that it is the more readily visible architecture of plants which is to be considered. It would be possible to study the architecture of a city without regard to the people who inhabited it or who erected the buildings.

DIFFERENT KINDS OF TISSUE

The cells of a plant do not exist separately, but are held together in groups. A group of cells of similar nature is called a

tissue. In a piece of elder pith or in an apple or a potato, nearly all of the cells are comparatively large and thin-walled. The resulting structure is somewhat soft, hence this may be called *soft tissue*. When cells form a skin or epidermis they constitute *epidermal tissue*. If cells are long and narrow and thick-walled, as are those making up most of the material in wood, they may be called *fibers*. If short and thick-walled, thus having strength and hardness, as the cells of a nut shell, they are known as *stone cells*. A piece of oak has various kinds of thick-walled cells and fibers which give strength and solidity.

The thin membrane which covers the leaves and young stems is called the *epidermis*. It commonly consists of a single layer of cells whose outer walls are water-proofed and thickened so that they serve very well to save the tender parts below from drying and from mechanical injury. But there are openings called air pores or stomata (Greek "stoma", a mouth) at various points, through which oxygen and carbon dioxide may pass in or out. As the stomata allow the passage of these gases, they also permit the escape of water vapor. There are special "guard cells" at the sides of the stomatal aperture which cause the opening to be smaller or larger, but their mechanism is not very efficient and the air pores are usually open in bright sunshine at the very time when there is the greatest danger of wilting.

Stems which are more than a year old, such as twigs or branches of trees and shrubs, are covered with *cork*. The cork does not look quite like the common bottle cork of commerce, being hard and rough and broken into ridges. Under the microscope, however, it is found to be of true cork structure. The cells are flat, and of rectangular brick-shape with thin water-proof walls. They protect the plant against water-loss through evaporation. In regions with cold or dry winters, or with very hot summers, the only trees and shrubs which can survive are those with a good development of cork. In Colorado, the twigs of trees and shrubs develop cork toward the end of the first growing season.

TISSUE STRUCTURE COMBINING STRENGTH AND LIGHTNESS

The arrangement of cells and tissues in plants is such as to combine strength and lightness. Stems, as a rule, have the strengthening tissue near the surface and soft tissue within, or

sometimes the central part of a stem is quite hollow. In either case the principle of the hollow cylinder is employed. If a stem is three of four-angled instead of being cylindrical, there is usually a strand of strengthening tissue at each of the corners.

The stresses to which stems are subject are those of bending and twisting rather than pulling, hence the hollow cylinder

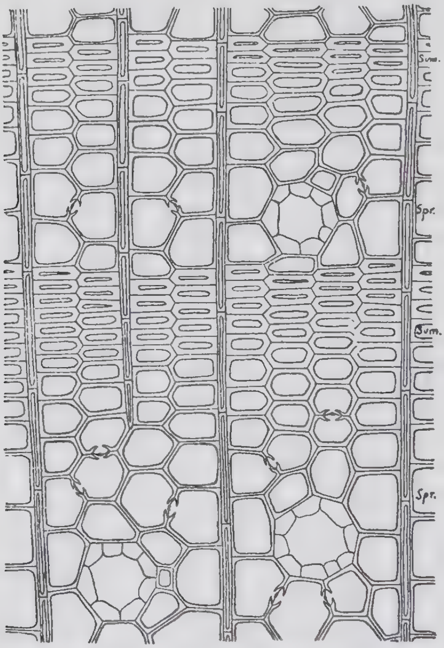


FIG. 114. Cross-section of piece of Pine Wood, magnified 500 times. The long vertical rows are the wood rays. *Sp.*, the spring wood; *Sum.*, the wood formed in summer.

construction is just what is needed. A root, on the contrary, does not need to be rigid, nor to be protected from bending. In fact, the growth of roots between pebbles and large soil particles naturally results in a bent or twisted form. But a root must be strong to hold the plant firmly in the ground. It must not be torn easily by a pull. So roots, in their architecture, do not follow the hollow-cylinder plan. Such soft tissue as is needed to carry on life processes is placed toward the outside, while the strong cells and fibers are within.

STRENGTHENING TISSUES

Strengthening tissues in plants are of two kinds. There are "stone cells" and long fibers. Stone cells occur in groups in the flesh of the pear, and give this fruit its characteristic gritty feel to the teeth. They form practically the entire shell of a cocoanut. In the bark of many trees, as cinnamon, there are large stone cells. Bark has very many strong thick-walled fibers. An expert who is skilled in the examination of foods and drugs can tell the different kinds of Peruvian bark by microscopic study of the stone cells and fibers, and he can distinguish various sorts of cinnamon bark even in the powdered state. Stony-walled cells lose their protoplasm when the walls have become thick; they take no part in the true life processes of the plant, serving only as structures for support.

Stony tissue is not abundant in trees, except in the bark, since the fibers and vessels of the wood furnish the needed strength. In herbs and climbing plants, a considerable amount of stony tissue is likely to be developed. Often a continuous band of thick-walled cells is placed close inside of the epidermis, or it may form irregular patches, thus producing an interrupted ring of strong and resistant material.

Since strength is required in both stem and root, it might be asked why plants do not build up their bodies entirely of strong tissue and dispense altogether with soft tissue. The answer would be, of course, that there are other functions to be served besides those of strength and protection. A man's leg gets its rigidity from the bones, and it is protected from injury by the skin, but it would not be desirable to have the leg constructed entirely of skin and bones. So with plants; the soft parts have their special work to perform and they are as necessary as the tougher and harder portions. Every plant must possess soft tissue, but only those of some size need strengthening tissues. Leaves are chiefly soft tissue, except their veins and epidermis. The inner bark of stems is also soft. The common fruits, as apples, pears, oranges, and watermelons are composed almost altogether of soft, watery material; but unless overripe they still show a characteristic cellular structure, and each cell has its wall, cytoplasm, and nucleus.

PHYSIOLOGY OF THE SOFT TISSUES

It is in the soft tissues that the real life work of the plant is done. Food making, the production of more protoplasm, and the other activities concerned with growth, repair, and reproduction belong to these parts of the plant. Photosynthesis, or production of sugar, takes place in the soft tissue of leaves, where the green substance cholorophyll is present. The sugar is made of water, obtained from the soil, and carbon dioxide, taken from the air. These two simple substances, as elsewhere described,

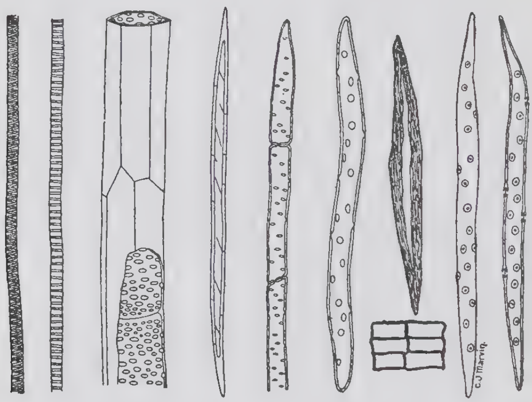


FIG. 115. Vessels, fibers and other cells taken from vertical sections of stems. (All highly magnified.)

are put together in the chlorophyll when the leaves are receiving light. Sugar formed in this way may be converted, at a later time, into other foods and be built up into protoplasm, or it may be changed to cellulose for the construction of cell-walls. Respiration, that is, the oxidation of food with release of energy, takes place to some extent in all living cells, but is especially active in the soft tissues of leaves and young stems.

LEAF ARCHITECTURE

The architecture of a typical leaf is suitable for the carrying on of the leaf's duties. Immediately below the upper epidermis

of the leaf, there is a layer of cylindrical cells placed side by side like pickets in a fence, and to which the name palisade has been given. When light shines directly upon the face of the leaf, the rays may penetrate far into the leaf, extending through the long diameter of these palisade cells. Light thus reaches a great number of the chlorophyll bodies closely packed in the palisade cells. Below the palisade, most of the leaf cells are irregular in form, with bulgings and even branches, between which are air spaces. This part of the leaf is known as the spongy tissue. In the air spaces there is a slow movement of oxygen, carbon dioxide, and water vapor; these gases diffuse slowly now one way and now another, as there may be a greater or less amount of each gas here or there. The air spaces of the spongy tissue communicate with the external world by means of the air pores (stomata).

Veins of the leaf are built chiefly of strong, tough, fibrous cells which give firmness to that which would otherwise be a very delicate structure. But they serve other purposes than that of mere mechanical support. It is through the veins (technically known as vascular bundles) that water is distributed to the parts of the leaf, coming through the stem from the roots which absorb it out of the soil. Certain cells of the veins are concerned with the transport of manufactured food from place to place within the plant. (Fig. 28.)

Special Internal Structure of Leaves and Stems

Internal structure is often suited to the environment in which the plant lives. Many plants which grow in water or in marshy ground have long cavities extending through leaves, stems, and roots. These afford a passage for air which is needed in all the living parts. Air is not readily secured by submersed plants, or by those which have their roots in cold, wet soil of bogs. Cat-tails, bulrushes, and pond-lilies have these air cavities, as have also the common cultivated calla of house windows, and the celery of our dinner table. Strengthening fibers, so important for stems of land plants, are usually absent from plants which grow under water. The water holds the plants up, and they do not need to have strength of their own. The delicate sea-weeds of the ocean floor, as well as the fresh-water bladderworts and pickerel weeds collapse into formless masses when removed from the water.

THE ARCHITECTURE OF WOOD

Wood is such a valuable product that a knowledge of its architecture should prove of interest. Not all woods are alike in cellular structure, just as they are not all alike in visible properties. The more easily recognized features of various woods depend upon the particular kinds of cells which compose them and upon the way in which these cells are arranged or built into the wood structure.

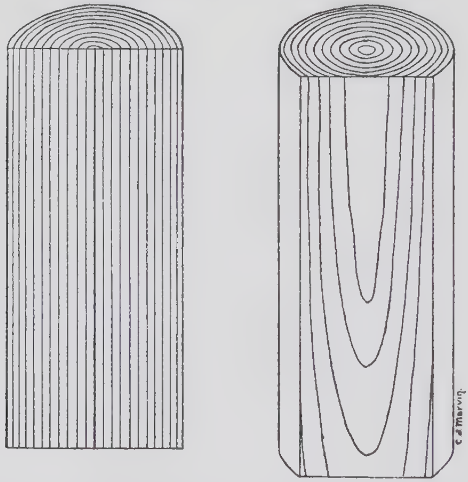


FIG. 116. Diagrams to show Structure of a piece of Wood. The annual rings are indicated. The cut surface of the left-hand figure shows the grain of quarter-sawed lumber; the right-hand figure shows ordinary grain.

The different shapes or general types of wood cells are three: (a) fibrous cells, long and pointed; (b) vessels or ducts, of large caliber, often quite long and composed of many cylindrical cells placed end to end; (c) short rectangular cells. All of these are thick-walled when mature and they are dead, with the protoplasm dried up and no longer visible. The vessels of oak wood are large and numerous, those of maple are small, while there are no vessels at all in cypress or pine. These cellular differences determine the qualities of the different woods. Rose-wood, calamander, and ebony owe their hardness to the small thick-walled cells of which they are composed.

While wood is especially well developed in trees and shrubs it is just as truly present, though in small amount, in the stems

of herbs and in the vascular bundles of leaves and roots. A sunflower stock or the stem of almost any common herb has a circle of vascular bundles a little way to the inside of the epidermis. Each bundle consists partly of wood (technically, the xylem) and it is in the wood of the bundles that sap travels upward just as it does in the wood of typical "woody plants". Along with the wood, but forming a distinct part of the vascular bundle, are thin-walled cells forming long strands which serve as passageways for solutions of sugar or other foods. These thin-walled cells, taken together, constitute the bast (technically, phloem). The bast of trees is located in the inner bark, next to the growing tissue which forms new wood and new bark each year.

The vascular bundles in the stem of grasses, such as Indian corn, wheat, bamboo, or blue grass are not arranged in a single circle, as in many plants, but appear scattered through the stem. This arrangement of bundles in more than one circle occurs also in palms, lilies, and all plants of the group known as monocotyledons. Such plants, even when of a "woody" nature, do not make annual rings of growth, for there is no continuous growing layer of cells (technically, cambium) such as exists between the wood and bark of most trees and shrubs. Wood of palms has much the same structure as a corn stock, except that it is harder. It is very different from wood of most trees. The cut end of a piece of cocoanut wood shows strands of strong and tough material scattered through a more porous part. On account of this peculiar structure the wood of palms can not well be used for lumber. It is coarse and easily splintered and does not withstand wear.

ANNUAL RINGS; GRAIN OF WOOD

Annual rings of wood show differences in structure of the various parts of each ring. The wood which is formed in the spring is more porous than that produced in summer. If vessels are present they are of larger size and more numerous in the spring wood. Such is the condition in wood of the oak. In woods without vessels, as spruce and pine, the cells formed in the early part of the growing season are large and have thin walls. Cells formed toward the close of each growing period are small and thick-walled. There is thus a sharp contrast in structure between the wood produced in late summer of one year and that of the

following spring. This difference in structure makes it easy to count the rings of growth in a stump or log, and it is the cause of much of the "grain" of wood. The alternating stripes of dark and light wood in boards of oak or hard pine flooring are the visible expression of microscopic differences in the cells of the wood.

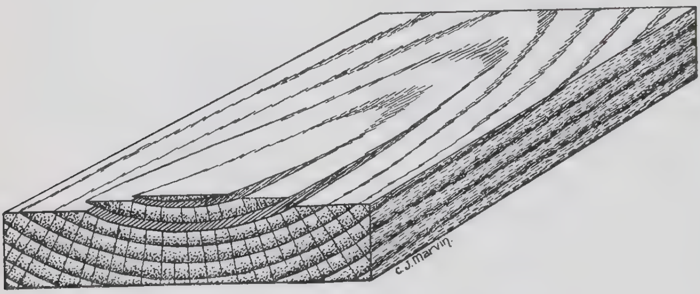


FIG. 117. Piece of Oak. The upper surface shows ordinary grain.

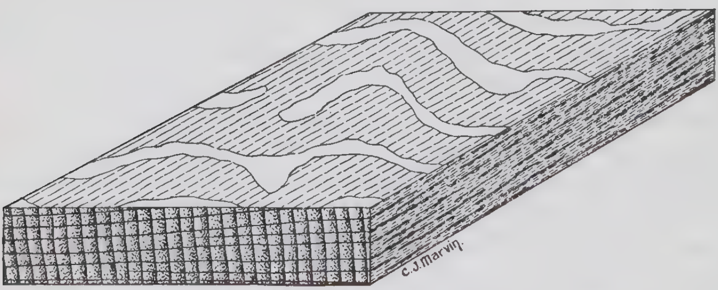


FIG. 118. Oak Board. The upper surface is quarter-sawed. Irregular clear areas are "silver grain".

The handsome grain of boards often seen in doors, and casings, or in furniture, is brought about largely by the differences in structure of spring and summer wood. Some kinds of timber have little of the lighter-colored spring wood and much summer wood. In others these proportions are reversed. Growth rings of some years are wide and of other years narrow. The wood may be produced in symmetrical manner, leading to straight grain in the boards, or the rings may be thick in some places

and thin in others. Boards cut from wood of such construction will show grain of intricate patterns.

Lumber for floors or inside finish or for furniture is called "quarter sawed" or "quartered" if it is cut in radial section, and it is called "plain" or ordinary when cut tangentially. In making quarter-sawed lumber, the log is first divided into four parts, and then each part is sawed as indicated by the lines in the drawing. (Fig. 119.) Of course, only the first board cut in any plane is exactly radial but two or more others may be cut which are nearly so. Other methods of quarter sawing may be used, but this one will serve for illustration. If logs are cut up into parallel boards, as in the left of the figure, a few at the center only are quarter sawed, while the greater number will be of plain or ordinary grain.

Quarter-sawing makes apparent the so-called *silver grain.* This is produced by growth of cells which form radiating strap-shaped bands of tissue (wood rays) extending through the wood. Some of the rays may run the whole distance from the pith at the center of the log out to the bark; others pass through only a few of the rings of wood. Oak, because of its large wood rays, shows beautiful "silver grain" when quartered.

PHYSICAL PROPERTIES OF WOOD

Different woods are employed by man for divers purposes. Hickory, so much in demand for ax handles, depends for its hardness and elasticity upon the individual cells which compose any stick of the wood. The hardness and heaviness of ebony are due to the close texture, thick walls, and large percentage of mineral matter. Maple wood is useful for the sounding boards of pianos, because it is of even texture throughout, with no large vessels. Soft pine is an excellent wood for general purposes, because it is easily worked and since nails do not cause splitting. All of these qualities are the result of the cellular structure of the wood.

USEFUL PLANT FIBERS

Vegetable fibers are important for various useful arts. Cotton is formed of the long hairs attached to the seeds of the cotton plant. When a cotton thread is examined under the microscope it is seen to consist of a great many very fine fibers, each of which is a flattened hollow cylinder. The fibers are, for the most part,

much bent and twisted, but they are plant cells just as truly as are the cells of a potato or apple. Linen is made of fibrous cells of the flax stem. These fibers are stronger than those of cotton because walls are thicker. By the use of the microscope it is a simple matter to distinguish any admixture of cotton in a linen fabric.

The various kinds of rope, twine, and matting are prepared from vegetable fibers which are simply long cells usually with thick strong walls. The coarser fibers, such as manila and sisal,

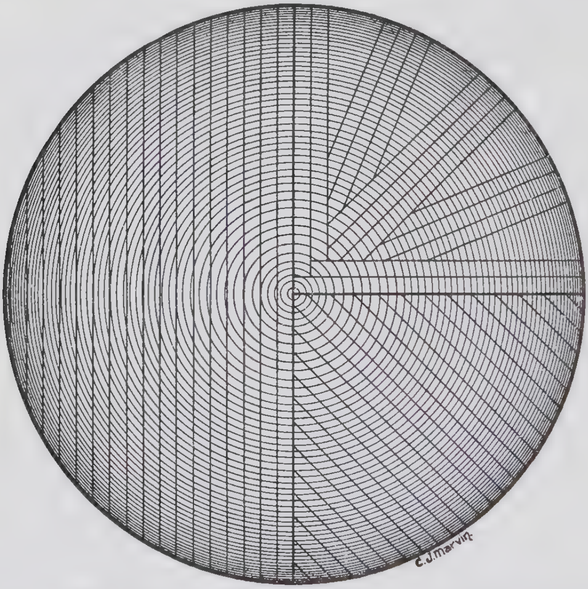


FIG. 119. Diagram of Cross-section of a Log of Wood. The left half is cut into boards in the ordinary way with only a few boards near the middle quarter-sawed. At the right are shown methods of producing more quarter-sawed boards. The upper right quadrant will furnish boards with the best "silver grain".

are prepared from entire vascular bundles, but hemp and jute are of the same general nature as linen, for they are made of the true bast fibers only.

Wood-pulp, used in paper making, is composed of wood fibers which have been shredded apart by mechanical rubbing on a grindstone or else separated by chemical means. The ancient Egyptians made a substance which served as paper from the stems of papyrus, and the Chinese made paper in very ancient

times from the fibrous inner bark of the paper mulberry, from rice straw, and from silk. In later times, paper was made from linen and cotton rags, and the best paper is still produced from these materials. Wood-pulp, now employed for all cheaper papers, was first used in the latter part of the 19th century.

Various kinds of wood may serve in making paper-pulp, but in the United States spruce, pine, and poplar furnish most of the wood-pulp supply. In the Rocky Mountain region there are no paper mills operating at present, but with the large amount of spruce and lodgepole pine it is desirable that paper making be introduced. What is needed to make the industry a success is some method of utilizing small trees and the slashings from larger ones.

* * * * * *

Of the different useful plant structures, a knowledge of internal makeup gives reasons for their employment. Discovery of the economic value of a particular wood, bark, or fiber is made from time to time by botanists at work with their microscopes, when "practical" men with no knowledge of plant architecture have passed the object by, thinking it worthless.

Chapter 15

FLOWERS, FRUITS, AND SEEDS

The flower is to most people so important a part of a plant that the word "flower" is often used instead of "plant". The flower is truly of great consequence because the continued existence of most species of the higher plants depends on flowers. Flowers are the forerunners of fruits and seeds; without the flower there can be no seeds and no new generations of plants.

It is an interesting fact that the early students of plants, 3,000 years ago, paid little heed to flowers and were much more interested in roots, bulbs, and other underground organs. These members of the plant body often serve for purposes of reproduction just as flowers do, but the ancients were interested in the underground parts not because of their propagative power but as sources of medicine. Plant descriptions among the Greek and Egyptian writers were full and complete as to roots but often failed altogether to mention the flowers. The botanist of those days was often also priest and physician. He was not concerned with philosophical aspects of nature, nor did he commonly turn his mind to the ornamental value or even food properties of plants. He thought of plants as the source of material for magic potions or for the more prosaic business of healing disease.

Theophrastus (370-285 B. C.), Greek father of botany, had an interest in plants for their own sakes as objects of nature. The writings of this early botanist describe the roots, stems, and leaves of the plants which were then known, but they tell little, almost nothing, of the flowers. Surely such conspicuous objects as the wild rose and lily or the blossom of the cultivated apple and plum could not escape notice and occasional mention among the ancients, but flowers did not really come into their own until modern times.

Parts of a Flower

The four chief parts of the flower should be understood; shall we say by all who claim to be educated? It is difficult to talk intelligently about the conspicuous plants of field and garden unless one can use the terms: sepals, petals, stamens, and pistils. The flower may be thought of as a branch which bears leaves very

close together, and these leaves are all more or less different from the common green foliage structures. In examining or describing a flower the leaves (sepals) at the base of the flower are first considered. They are ordinarily green and of small size, of leaf-like appearance. Next above the sepals are the petals, often colored and usually thin and delicate. Above the petals, or more often inclosed by them, are the stamens, each consisting of a slender stalk upon which is borne a tiny yellow casket containing grains of pollen. At the center of the flower are the pistils, or it may be that there is only one pistil. It is in the lower part of the pistil that the seed-rudiments are formed.

Pollen grains, whether from the stamens of the same flower or from another flower, are brought to the pistil-tip by air currents or by insects. The grains sprout, producing the pollen tubes which extend down through the pistil into the seed-rudiments; these last enlarge rapidly and ripen into seeds.

The stamens and pistils are often called the essential organs of the flower because concerned with seed production. The sepals and petals are spoken of as the floral envelopes.

SEPALS

As already stated, the sepals look much like very small foliage leaves. They are commonly green. But in some flowers, as the clematis and pasque flower, only one set of enveloping leaves is present. When this is the case, botanists call the parts sepals, even if not green and although they are of such delicate structure that they would naturally be considered petals. Sepals then are not always green and leaf-like. The sepals of some flowers are white or pink or purple, rather than of a modest green. In most flowers, but not in all, there are exactly as many sepals as petals.

PETALS

The conspicuous parts of a typical flower are the petals, and it is doubtful if any educated person does not know this word and apply it with some degree of correctness. Wild roses have petals which are white, pink, or red; the petals of many evening-primroses are yellow, and those of harebell are blue. Flowers in some families do not have distinct petals but have instead bell-shaped, trumpet-shaped, or funnel-shaped colored structures from whose edges a certain number of teeth or rounded lobes extend. The

garden petunia and Canterbury bells furnish examples of these so-called "sympetalous" flowers, while among Colorado wild flowers the harebell, phlox, and lungwort can be named. Another specialization of petals is found in such "irregular" flowers as larkspur, violet, monkshood, and the members of the pea family.

STAMENS

The stamens, because of their small size, attract little attention and yet they are very essential parts of the flower, for they produce pollen grains. In order that seed can be produced, pollen grains must reach the upper part of the pistil where they sprout and form pollen tubes, which grow down into the seed case. It is only when one of the tubes has actually penetrated a seed-rudiment that this seed-rudiment can complete its growth and ripening. Many flowers have just twice as many stamens

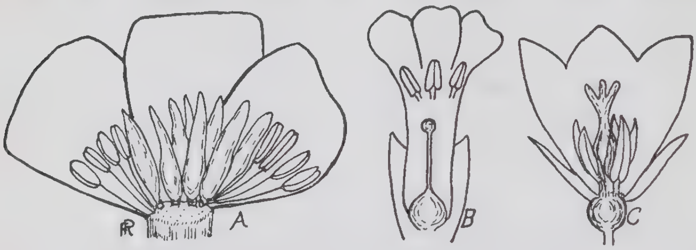


FIG. 120. Drawings of Flowers. These are split open to show structure. *A*. Rather simple type of flower in which all of the parts are separate; *B*. Higher type in which sepals are united, petals are united, stamens are attached to the inside of the corolla-tube; *C*. Still higher type, with ovary (fruit-rudiment) below the flower.

as there are petals, and this is probably a rather primitive and ancient condition. There are flowers, however, with a reduced number of stamens, in which cases it often occurs that small stamen-rudiments are recognizable in the places where we should expect to see good stamens.

PISTILS

Pistils are usually fewer in number than the other three chief parts of the flower. Often there is only a single pistil which, however, usually shows in some way that it is a compound structure. The tip may be divided into two, three, or more prongs, and the lower part, which holds the seed-rudiments, may consist of a number of chambers. In flowers with five petals it often is the case that the number of seed-chambers is also five. This lower

part of the pistil is the fruit-rudiment, and as growth and ripening proceed it may form a pod or a berry or a stone fruit or a dry one-seeded nutlet or whatever type of fruit belongs to the particular plant.

The fruit-rudiment, or ovary as it is called, is not always within the flower, i. e. inclosed by the floral envelopes, but may be under the flower. In this case, the sepals and petals appear to grow out from or be attached to the top of the ovary. Such flowers are said to have an inferior (lower) ovary, and this form of floral structure seems to belong to the more recently evolved and more high specialized families of flowering plants.

Spiral and Cyclic Flowers

The arrangement, or placing, of the sepals, petals, stamens, and pistils upon the axis of the flower-stalk, is not the same in all flowers. Botanists think that the first flowers which appeared upon the earth in far distant geologic time had their various parts attached to the axis one after the other in the form of a spiral. Toward the base of one of these primitive flowers were what might be called sepals, occurring singly, one after another, and forming such a spiral as does the red band of a barber's pole. Continuing, there came next the petals, then the stamens, then the pistils. Probably these various structures graded into one another. Only slightly modified from such a primitive type are the present-day flowers of "strawberry bush", tulip tree, and marsh marigold. As time went on, some flowers developed the four distinct flower-parts which now usually occur. The sepals came to form a definite circle, followed by a circle of petals, and these again by circles of stamens and pistils. All of those plant families which are considered as most highly evolved have such cyclic flowers (the parts arranged in circles) instead of spiral flowers. The spiral flowers belong to lower or more primitive families.

High and Low Types of Flowers

Flowers may be classified as of low type or high type depending on whether they are more or less primitive in structure. If a flower has the parts arranged spirally, if the sepals are numerous and all distinct, the petals distinct and separate, the stamens and pistils numerous,—it is called a low-type flower. Any modifications make the flower "higher".

Although there are various advanced families of flowering plants, such as the lobelias and the orchids, the "highest" family is probably that of composites, including the sunflower, aster, daisy, thistle, and dandelion. Such plants have very small flowers, collected in a flower-head. In the thistle and dandelion, the numerous individual flowers of the head are all alike, but sunflowers, asters, and daisies have flowers of two kinds; those in the center of the head are of small size and tubular form, while the outer ones, the rays, are often large and conspicuous, with the appearance of expanded petals. It will be remembered that a sunflower or a daisy (Plate II) is not a single flower but rather a flower-head or flower-cluster.

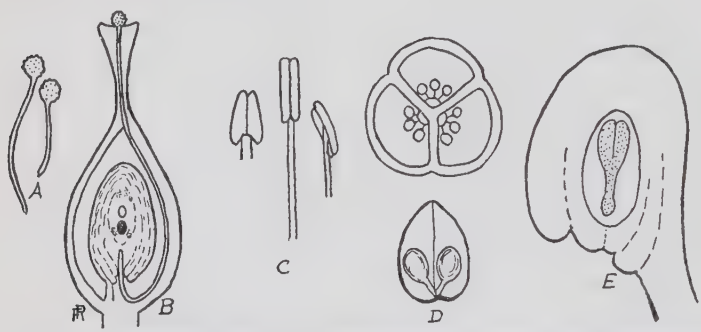


FIG. 121. Details of Flowers. *A*. Pollen grains which have sprouted and have produced short pollen tubes. *B*. Section of a pistil showing the seed-rudiment below, into which a pollen tube is growing; the egg solid black; *C*. Stamens of different kinds; *D*. Cross-sections of ovaries (fruit-rudiments); *E*. Section of young seed-rudiment, containing the developing embryo or young plant within the embryo sac. *A*, *B*, and *E* are highly magnified.

INCONSPICUOUS FLOWERS

Not all flowers are large or of bright color. In some, the floral envelopes are minute, their color brown or green. Others are entirely lacking in sepals and petals. Yet in every functional flower at least one set of the essential organs, stamens and pistils, must be present. Willows and cottonwoods have very simple flowers in long clusters called catkins; certain of the trees bear only staminate clusters, while the other trees are pistillate. The staminate and pistillate trees are essentially alike except in their flowers. Naturally, it is only on the pistillate trees that seeds are developed. Besides cottonwoods and willows, there are many other trees whose flowers do not attract notice: as maple, alder, birch, and oak. But it must not be concluded that trees are

always without conspicuous flowers; the reader needs only to be reminded of flowers of the catalpa, locust, peach, apple, and cherry. Among herbs, the grasses and sedges have no brightly colored parts, and the flower clusters of lamb's quarter, plantain, pigweed, and ragweed are also lacking in color, so that to most eyes they appear altogether unattractive.

Pollination

Reference has been made more than once to the influence of pollen in stimulating the growth of the fruit-rudiment and the ripening of seed. The pollen grains, when they become mature, may sprout upon the pistil of the same flower in which they were produced but it is more usual that they are transferred to some other flower. In the first case, self pollination is said to occur; in the second case, cross pollination. Among sunflowers, cross pollination only is of value, for no seeds are ripened unless this takes place. With dandelion, cinquefoil, and chickweed both self and cross pollination occur, while among many plants of the pea family, grass family, and certain others self pollination is the rule.

The transfer of pollen from stamen to pistil may occur by contact in self pollinated flowers, but usually the pollen is carried by air currents or by insects. Fossil remains show that the higher insects and the more complicated flowers have had a somewhat parallel history. In past geologic times, when butterflies, moths, and bees became numerous and of many kinds, flowers also took on greater elaborateness of structure; or to state the case from the side of plants: as new types of flowers came into existence there soon developed new insect forms especially well able to effect their pollination.

Flowers with long tubes, such as honeysuckle and phlox, are visited by bees, butterflies, or moths, having a long tongue, or proboscis. These insects are able to get the nectar which is produced at the lower end of the flower-tube. More open types, as buttercups and pasque flowers, attract also flies and beetles; but even among these the chief pollinating agents are butterflies and bees.

Insects do not visit flowers for the purpose of carrying pollen, however praiseworthy such a motive would be. They go in search

of nectar or pollen or both of these. In alighting upon or entering a flower the insect brushes against the pollen sacs and some of the pollen is dusted upon its body. In the next flower, this pollen may be rubbed off upon the receptive tip of the pistil and the act of pollination is thus completed.

GROWTH OF POLLEN TUBE; FERTILIZATION

Pollination is not fertilization; it is merely preliminary to it. When the pollen grains reach the receptive tip of the pistil they send down these delicate outgrowths, the pollen tubes already mentioned,—one from each pollen grain. The tube grows through the material of the pistil just as a mildew or rust fungus

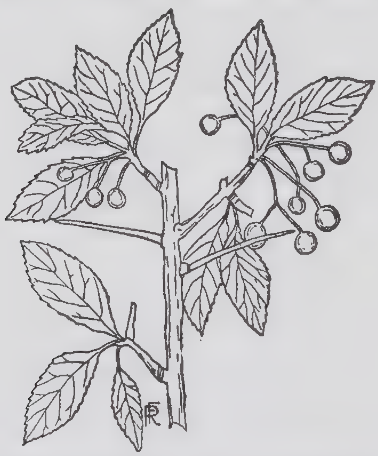


FIG. 122. Small-leaved Thornapple. Native of western Colorado. Planted in parks and public grounds as an ornamental tree. Other thornapples, native to the State, also are valuable for planting.

grows within a leaf or stem, by producing a chemical substance which dissolves away the parts of the plant with which it comes into contact. When the tip of a pollen tube finally reaches the interior of the ovary, the tube bends in the direction of one of the seed-rudiments and penetrates it. The end of the tube now bursts, discharging two minute worm-like bits of living matter, the sperm-cells. One of these unites with, or fertilizes, the likewise minute, although larger, egg which is present in the seed-rudiment. The other sperm becomes associated with the part of the seed-rudiment which gives rise to the food material of the seed. True fertilization is neither the transfer of pollen nor the

growth of the pollen tube, but rather the fusion of the two microscopically small bits of living substance, the sperm and egg.

RIPENING OF SEED AND FRUIT

The fertilized egg grows, divides, and its parts multiply in definite and orderly fashion until a tiny plant, the embryo, is formed within the ripening seed. After a period of rest, the ripe seed sprouts, if suitably environed, and the embryo becomes the seedling, or young plant.

During the time that the seeds are developing within the ovary, or basal part of the pistil, the ovary itself enlarges and becomes the fruit. The ovary wall in some cases attains to a soft and juicy state, as in such fruits as plum, cherry, grape, and blueberry, or it develops a hard, stony coat, as in the hazel nut. In some flowers, the ovary lengthens out to form a pod-like structure (golden pea, milkweed, Colorado bee plant).

A full discussion of the many forms assumed by the fruit belongs rather to a text book of botany than to a work on the plant life of Colorado; it may not be amiss, however, to state that the word "fruit" as employed by botanists has a much more inclusive meaning than when used by the ranchman or grocery clerk. The familiar question as to whether a tomato is a fruit, is answered in the affirmative by the botanist because a tomato is a ripened ovary. By the same token, an egg-plant is also a fruit, and so are cucumber, wheat grain, sunflower "seed", pea pod and cocoanut.

DEVELOPMENT OF EMBRYO PLANT FROM THE EGG; THE "WONDER OF WONDERS"

As stated earlier, the sprouting seed gives rise to the seedling or young plant. This plant is not newly formed at the time it appears above ground. It was already present in the seed, usually having stem and leaves fully formed, although of small size. A knowledge of the presence of the young plant in the seed may take away some of the mystery which surrounds the development of the seedling, for seed sprouting is merely a resumption of the growth of the embryo,—the continuation of a process which brought about seed ripening. But if there is less of mystery and wonder here, there is the still greater marvel of the development of the embryo from the minute fertilized egg. The egg, a mere

bit of jelly-like living material becomes by growth, division of parts, specialization, and more growth, however slowly yet surely, the adult organism.

"The wonder of wonders" to the biologist is how one tiny particle of living substance, too small to be seen save with the compound microscope, can develop certainly and without fail into a young cottonwood tree; how another such speck can produce a rose bush and how still another makes a poppy, or a grass, a sunflower, or a pigweed.

Within the egg and sperm are the master factors which determine what the offspring shall be. Unfavorable environment

FIG. 123. Mountain Privet. Native to southern Colorado, desirable as a hedge or screen shrub. Genus Forestiera. (Sketch made from a specimen furnished by D. M. Andrews of the Rockmount Nursery, Boulder.)

may cause a plant to be stunted or to die; favorable surroundings make it robust and fruitful, but no kind of environment modifies the germ cells so that they will give rise to offspring essentially different from the parent. A certain kind of plant will succeed in some climates while in others it is sure to fail, but climate does not alter the true character of the plant. No outside influence will change rye plants to wheat, cause a rose bush to have blue flowers, convert Ben Davis apples into Jonathans, or make a sunflower egg develop into anything but a sunflower plant. And so, it may be said that beyond all other wonders of the world is the development of a complicated, highly-organized living plant (or aminal) from a minute bit of jelly-like substance, the fertilized egg.

HOW LONG DO SEEDS LIVE?

The length of time during which seeds will keep their ability to sprout varies much with the kind of seed and with the conditions of storage. If put away in suitable containers after first being exposed to warm dry air, seeds may keep their vitality for a long period of years, although in the humid atmosphere of the tropical rain forest, most seeds lose their power of growth within a few days or weeks. Very small seeds deteriorate quickly, but such grains as wheat and corn will, if properly stored, retain their growing power for as long as thirty or more years. Peas and beans, as well as certain weed seeds, have been known to sprout after a period twice as long. It need hardly be stated that stories of the sprouting of "mummy wheat", that is wheat 3,000 years old from the tombs of Egypt, are more interesting than accurate.

SEEDLING STAGE OF PLANTS

The seedling, or young plant developed from the seed, is an interesting stage in the life of herb, shrub, or tree. Many people know something about seedlings of garden plants, as the radish, beet, bean, pea, and Indian corn. The seed-leaves of the three first named come above ground in pairs, those of pea remain underground. In corn there is nothing quite corresponding to the seed leaves of these other plants, the first part to appear above ground is a foliage leaf. Seed-leaves, or cotyledons, as they are technically called, are sometimes leaf-like but more often thickened with an accumulation of food so that they do not look exactly like the ordinary leaves.

Not many Colorado plants have been studied in the seedling stage, nor indeed have the seeds themselves been investigated. Here is an opportunity for botanical workers. Knowledge of these subjects is needed; it can be secured by any one who has some skill with the simple microscope, a modicum of patience, and a desire to add a little to the world's store of knowledge.

PLANTS, AND MAN'S WELFARE

Related to the topics of this chapter are certain matters of interest which may well receive some attention. The fruits and seeds of cultivated plants have for thousands of years been man's great source of food. In Europe and western Asia the cultivation of wheat and barley was carried on long before written history;

in eastern Asia, rice growing is probably almost as old. The apples, plums, and cherries of Europe and the oranges of China likewise have been grown and eaten for many centuries. The fruits and nuts of the Torrid Zone were, no doubt, important articles in the diet of early human dwellers in the tropics, just as today they bulk so large in the fare of apes and monkeys. But these general matters need not be considered now; attention may be turned to some questions of definite local interest bound up with flowers, fruits, and seeds in Colorado. First to be mentioned will be hay fever, then useful fruits and seeds, then ornamental plants.

FIG. 124. Native Ornamental Shrubs. *A.* Dwarf Alpine Birch; *B.* Nine-Bark; *C.* Dwarf evergreen Oak (Quercus undulata).

HAY FEVER

The distressing condition known as hay fever, and its close relative bronchial asthma, were known long ago, but it is only in the 20th century that they have received much study. Pollen is the cause of hay fever, but not all pollens can be blamed in this matter. It has been discovered that the injury which they cause is not due so much to their dusty nature as to the chemical substances which they contain. The sedges and grasses both pro-

duce great quantities of pollen, but the pollen of sedges seems to have no material deleterious to the health of man, whereas many grasses cause severe hay fever in the unfortunate susceptibles. Walnut pollen affects some victims but the pollen of pine appears to be quite innocuous.

Among hay-fever plants in Colorado, after certain of the grasses, mention may well be made of the plants of the goosefoot family, as Russian-thistle, lamb's quarter, and fire-ball (Kochia), then the ragweeds, as ugly as their name, then the mountain sage. Fortunately, mountain sage affects comparatively few people. The great majority of sufferers from hay fever find relief in the higher altitudes (above 7,000 feet) where the offending grasses, the members of the goosefoot family, and the ragweeds are absent or rare. It is true that other plants than those already mentioned are responsible for individual cases of hay fever but it is these which are of especial consequence. No plant is likely to produce hay fever unless it spreads large quantities of light, dusty pollen, easily carried about by air currents. If pollen is heavy, sticky, or of small amount it makes little trouble, however toxic it may be.

It is within the range of possibility to render a city or town free from hay fever. Many people find that in down-town districts they have no hay fever while in the suburbs they may suffer great distress. These facts suggest at once the means for eradication: pave the streets, and keep weeds cut down. No doubt, a thorough campaign of weed cutting would reduce to a minimum the hay fever of any community. People who destroy a piece of natural vegetation and then abandon the ground, are offering a place for the growth of weeds. It would be best if vacant city lots could be left in their original condition.

Useful Wild Fruits in Colorado

Of fruits and seeds useful to man among the wild plants of Colorado, there are not many. Wild strawberries are good but very small, choke-cherries are often abundant and used for jelly by mountain dwellers, wild plums in some years also are abundant. Wild grape and Oregon-grape make good jelly and jam. Residents of the mountains find blueberry bushes everywhere in spruce and pine forests of montane and sub-alpine zones but many seasons are "off years" and furnish little fruit. Wild raspberries are

fine-flavored and sometimes obtainable in quantity. The pinyon "nut", really a seed, is locally abundant and often gathered for sale; it comes from the pinyon pine of southern and western parts of the State. Hazel bushes, though common enough, seldom bear nuts in great quantity.

NATIVE FLOWERS FOR THE ORNAMENTAL GARDEN

Colorado has contributed many flowers for the ornamental garden. There is, to begin with the large blue columbine, the State flower, which is one of the seven species of columbine growing wild in Colorado. Botanically the plant is known as *Aquilegia coerulea*, the name given it in 1825 by Dr. Edwin James who was botanist of Long's expedition. The flower of the columbine is handsome because of its large and conspicuous sepals of blue alternating with the smaller petals of blue and white, each of which has a backward-projecting hollow spur. The blue native columbine is widely distributed throughout the mountain districts of the State, from about 6,500 feet to 11,500 feet altitude. It occurs also, less abundantly, in New Mexico to the south and in Wyoming and Montana to the north. At high altitudes the flower color is often pale, the flowers of some plants being altogether white. The blue columbine may be grown from seed, although it requires two years or more for it to reach the flowering stage. Nurserymen are beginning to raise the plants for sale, and it is much to be desired that they will develop the industry, so that motorists will no longer have an excuse for digging up wild specimens for transplanting to their city gardens.

Not only the blue columbine but the other native species also are highly ornamental; some of these others are occasionally cultivated. Columbines hybridize readily, and many amateur gardeners find pleasure in crossing different varieties and species. Columbine flowers sometimes do not have spurs. Of course, such flowers look quite unlike ordinary columbines and have more the appearance of a clematis. This particular type seems not popular for garden planting, although in appearance it is very attractive.

The beautiful gaillardias grown in flower gardens are native to Colorado. The annual form grows wild all the way to Louisiana, and was probably first introduced into cultivation from

that state or from Arkansas. The larger, perennial, species is more typically a Rocky Mountain plant. Gaillardias are somewhat sunflower-like in appearance but the central disk flowers are maroon, rather than brown. The orange-colored rays have a flush of red in the lower half much like the "red sunflower" mentioned in an earlier chapter. Gaillardias are among the most satisfactory of bed and border plants because of their long blooming period. They keep well as cut flowers.

Many other plants, native to Colorado and adjacent states, are suitable for garden culture and have been used to some extent by those who like to try something different from the regular favorites. No doubt, 100 or more different Rocky Mountain flowers would make satisfactory garden plants. Among these are the wild iris, perennial sunflower, Torrey's beard-tongue, tufted evening-primrose, pasque flower, Scott's clematis, sand lily, and tall chiming bells. Of plants cultivated more for general appearance than for their flowers, mention may be made of Colorado male-fern, the cacti, and wild rye (lyme grass). The soapweed, or yucca, is grown both for its interesting exaggerated grass-like form, and for the spike of large cream-colored flowers. Most of the yuccas in cultivation are from Mexico, but our soapweed yucca is also sometimes planted.

Native Ornamental Shrubs and Trees

Some of our native shrubs are grown for their flowers, others on account of their fruit, and still others because of their foliage or general graceful form. The flowering currant (*Ribes aureum* of the nursery trade), with its wealth of yellow flowers in early spring, is an old favorite. The red-bark dogwood is often planted for its handsome winter appearance. It lends a tinge of landscape color at a time when color is generally lacking. These shrubs are particularly beautiful when snow on the ground brings out the red of twigs and branches in fullest richness. Then there is the thimble-berry, with large white flowers like those of a single rose; it is coming into favor as an ornamental shrub. Another effective shrub in landscape gardening is the nine-bark, beautiful in late spring for its clustered flowers of creamy white and in midsummer for the red-tinged dry fruits. The western beaked hazelnut, native on the banks of foothill streams, can be

used satisfactorily for planting in clumps, as also the bush honeysuckle, or fly honeysuckle (*Lonicera involucrata*) of mountain marsh land.

Some Colorado shrubs for planting in dry places are: the wild mock-orange (Jamesia or Edwinia), the three-leaved sumac, Gambell's oak, the smooth mountain sumac (*Rhus cismontana*), buffalo berry, tall mountain privet (*Forestiera neomexicana*), and the pale box-thorn. The last-named plant is related to the well-known "matrimony vine". It has large pale-green flowers, followed by orange-red fruits. Mountain mahogany and dwarf indigo also thrive in rather dry and sterile soil.

Shrubby cinquefoil is a satisfactory border perennial, as is also the delicate "mountain-spray". Wild native clematis of the canyons does well on porch trellises where its small white flowers in great profusion during August are much like those of the more familiar, and later-flowering, Japanese species.

The native hawthorns have handsome flowers resembling cherry or apple, and in autumn attractive bright red fruits. One species with black fruits is called "black haw". A valuable small native tree is the fountain birch (*Betula fontinalis*), with rich dark-green leaves. It is beautiful in winter because of its graceful curved stems and shiny brown twigs, with drooping catkins. A relative of the birch is the western alder, which grows to a somewhat larger size. The various native cottonwoods are often planted. Better than any of the more common forms is the Andrews poplar, named for Mr. D. M. Andrews, of Boulder, Colorado. It seems to be a hybrid between the western cottonwood and the lanceleaf cottonwood. Like many hybrids in the plant kingdom, it is more vigorous and of more rapid growth than either if its parents.

The evergreens of the Rocky Mountains are much used in large grounds everywhere. Colorado Blue Spruce, the State tree, is a favorite for planting in parks of North America and Europe. The Douglas spruce does not grow so large in Colorado as it does in the Pacific States, but seedling trees and seeds from this State are in demand for planting. The Rocky Mountain cedar (*Sabina scopulorum*), the rock pine, white fir, and Siberian juniper are other valued evergreens.

No one part of the world has produced a great number of native useful plants. The species now cultivated by man have come from many localities; probably Colorado has furnished her full share in the various plants that have been mentioned. Those which are most definitely and unforgetably associated with the State are the Blue Columbine and the Colorado Blue Spruce.

Chapter 16

THE FLORA OF COLORADO

We do not know what plants first grew in Colorado. Since, however, very small and simple plants were the earliest to appear in other localities, it is likely that the early flora here too was made up of plants having little complexity.

It is well known that within the last few millions of years there have been no profound changes in limits of forests and plains of Colorado. Climatic changes have occurred; at times the higher mountains have been covered with ice, but at moderate altitudes the forests, grassland, and thickets occupy much the same areas now that they did in the Miocene and Pleistocene epochs. The plants growing here today are, in many ways, like the plants which flourished in those times of long ago. But, since all things have a beginning, there must have been a time when there were no plants at all in the area which is now Colorado. How did plants reach here? Where did they come from?

Geologists tell us that at one time in the world's history a mere chain of islands represented the land which is now the Rocky Mountain region. At various times these islands were raised high above sea level, then lowered, and again raised and lowered. When the islands were high they became connected by dry land, because the sea floor between them was raised at the same time. During those periods, the plants and animals of one island might spread to all of the group, that is, throughout the continent. For long periods, what is now the high western plateau was cut off from eastern North America by a great inland sea which stretched from the Rocky Mountains to the Appalachians, yet at other times there was dry land, across which plants and animals could travel.

So there were times when Colorado was much detached from the rest of the world, and other times in which the land connections were quite as close as at present. When climates were more mild than now a great many species of plants could live in the region of Bering's Straits and pass one way or the other across the land connections. At present there is very little inter-change of plants between Asia and America because the flora of the Bering's Straits region is so limited.

THE BLUE-GREEN ALGAE

The earliest plants to appear in any part of the earth, as judged by fossils from very old rocks, were of minute, even microscopic, size. These were the simple one-celled algae, such as grow on damp flower pots, or form a scum on half-dried mud. From these, in the course of ages, the larger and "higher" algae developed. No doubt bacteria were among the early representatives of that which was destined to be present plant kingdom. And perhaps soon after the bacteria came the simpler fungi, now so common as molds of various sorts. Still later, the "higher" fungi, as yeasts, mildews, and mushrooms, were evolved,—derived chiefly from the more advanced types of algae.

Wherever these various low forms of plant life first came into existence, they eventually reached to all lands. Such small organisms can be dried and blown by the wind for hundreds of miles; they begin active growth again if they fall on a moist surface. So, if there were simple plants in one locality they became spread to all parts of the world. This same condition exists at the present time; the simple forms of life are similar over all sections of the earth's surface.

The simplest algae that we know now are one-celled, of a blue-green color, and so small that very little of structure may be discerned in them. Often many cells are held together in mucilage, but each cell acts by itself and is hardly to be thought of as part of a many-celled plant.

THE BACTERIA

Bacteria are even smaller than the blue-green algae. Generally they are so minute that it would take a thousand to encircle the head of a common pin. Bacteria are abundant everywhere; probably any which would be gathered in a spoonful of garden soil today in Colorado are much like those which existed when life on the earth was young,—when there were no trees, no flowering herbs, not even ferns or mosses.

The blue-green algae and the bacteria are sometimes classed together as forming a branch of the plant kingdom called the Schizophyta (literally, "splitting plants"). They have been given this name because of their mode of reproduction, which is a simple splitting apart of one plant to form two plants.

It is hard to estimate the total number of species of schizophytes in Colorado. Probably there are a few hundred kinds. Many of them are soil-dwellers; they exist in all but the driest and most sterile ground. Soil bacteria are of consequence in improving the soil, for they act upon organic matter, derived from dead plant and animal remains, and they make it over into materials which are available for other plants.

Much has been said in popular writings about the "germs" which are everywhere around us, and by "germs" are meant bacteria. But, as already indicated, most bacteria live in the soil, carry on their own activities and bring harm to no creature. A few there are, and these we hear most about, which produce disease in other living things. Such are the germs of typhoid

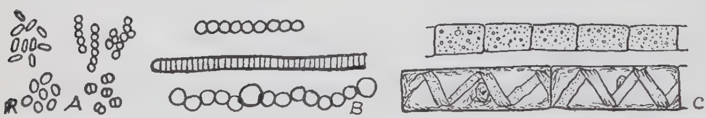


FIG. 125. Some Low Forms of Plant Life. *A*. Bacteria, four kinds; *B*. Blue-green Algae, three kinds; *C*. Green Algae, two kinds. (All enlarged: the bacteria x 1000, the blue-green algae x 500, the green algae x 250.)

fever, diphtheria, Asiatic cholera, and tuberculosis. Although these are interesting, they need not be described here, for they are considered in the health books with which every school child is familiar. Further than this, bacteriology is a highly technical subject and any full account of even the disease-producing forms would be a long story.

THE GREEN ALGAE

The green algae, most frequently appearing as floating thread-like growths in water, are far in advance of the blue-green algae. Indeed, they are so different that they deserve a name which will show that they are not the same. Green algae have much larger cells than do the blue-greens, they have a distinct nucleus in each cell, and the coloring matter is confined to the chloroplastids, which are definite parts of the living substance within the cell. Often the chloroplastids are relatively large, with only a few in a cell. They are not always of the common door-knob and foot-ball shapes which the chloroplastids of the flowering plants

Fig. 126. View in a Mountain Park (South Boulder Park, at Tolland, Colorado). In the dry grassland, may be seen a portion of a mushroom "fairy ring". In this picture, three life zones are shown: in front, the montane; farther back, the sub-alpine forest; in the background, the alpine zone of timberline and above.

assume. When examined under the microscope these large and conspicuous chloroplastids make the green algae very beautiful objects. The study of algae is most fascinating for the amateur naturalist who possesses a compound microscope.

The total number of species of green algae in Colorado is perhaps two hundred, but as complete collections have not been made it is impossible to give very exact figures. A search, conducted over a number of years, of the waters of streams, ponds, and irrigating ditches would yield an interesting list of green algae. The study of algae is called algology, and a botanist who devotes much of his time to algology is called an algologist. "Phycologist" would be a better term, for it is made of two Greek roots and is not a hybrid of Greek and Latin origin. Singularly enough, the study of fungi is not known as fungology, but as mycology; this word "mycology" can not displease even the most captious student of the classical languages.

Before considering the next group of plants, namely the fungi, it may make matters more easily understood if a brief synopsis of the plant kingdom is placed before the reader.

SYNOPSIS OF THE PLANT KINGDOM
(As represented in Colorado)

The Thallophyte Division:

- Algae; blue-green, green, and other colors. Examples: watersilk, pond-scum, green slime on flower pots or damp walls, "frog spittle".
- Bacteria; the bacteria, "germs", "microbes"; often included with fungi.
- Fungi; yeasts, molds, mildews, rusts, smuts, mushrooms, lichens.

The Mosswort Division:

- Liverworts; common liverwort, horned liverwort, leafy liverwort.
- Mosses; true mosses, peat mosses.

The Fernwort Division:

- Ferns; true ferns, water ferns.
- Horsetails; horsetails and scouring rushes.
- Clubmosses; small clubmosses (Selaginella) and large clubmosses (Lycopodium), "ground pine".

The Seed-plant Division:

- Lower seed plants; trees of the pine family, joint-fir family, and juniper family.
- Higher seed plants; the true flowering plants including herbs, shrubs, and trees.

THE FUNGI

Fungi are far more numerous in species than the blue-green algae, bacteria, and green algae all taken together. While there

were probably some fungi in Colorado and in the rest of the world at a very early period, the "higher" forms such as mushrooms, cup fungi, and especially the numerous species parasitic on flowering plants must be of relatively recent origin. The "lower" fungi, such as true molds and water-molds are much the same the world over. This fact indicates their great antiquity. Most of the parasitic fungi are able to grow only on certain species of seed plants; these fungi presumably have acquired their peculiarities since their particular host-plant appeared upon the earth.

The fungi do not contain chlorophyll; they can not make their own food. A supply of food ready-made must be at hand for their existence. The common molds use as food almost any material derived from plants or animals: dead bodies, secretions,

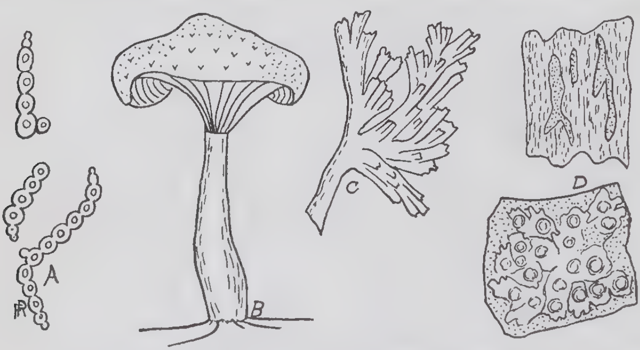


FIG. 127. Examples of Fungi. *A*. Yeast cells, highly magnified; *B*. Small mushroom; *C*. Coral fungus; *D*. Lichens, on bark and on rock.

excretions, discharges. Water-molds get their food from living or dead algae, or else they live upon the eggs or the bodies of aquatic animals. Rusts, smuts, and many other fungi are strictly parasitic, being unable to grow and reproduce unless they live upon or within the higher plants.

Many rusts have a complicated and interesting life history. One kind lives as a parasite upon pine or spruce. It injures or eventually kills its unwilling host. The spores which it produces every year sprout only upon wild currant or gooseberry. On the gooseberry leaves, more spores are formed. These will not sprout upon other gooseberry bushes but can develop only on pine again. Wheat rust, as is well known, goes to the barberry and then back to wheat.

Mushrooms are of interest because of their rapid growth, frequent handsome colors and, in some cases, pleasant flavor when cooked. Although many people think of mushrooms and toadstools as different sorts of plants there is really no clear distinction. Botanists call them all mushrooms, whether edible or not. It is usually not safe for the non-botanist to gather mushrooms for food. He is too likely to take home unwittingly a poisonous one. There is no sure, safe, and simple way to tell which mushrooms are good and which should be let alone. If one knows some certain particular kind to be edible it will be best to confine fungus eating to that kind, for it is much better to be safe than dead. One who is really interested may, however, learn the different kinds of mushrooms, for there are well-illustrated books which describe all of the common forms.

An interesting manner of growth is seen in the so-called "fairy rings" of pastures and native grassland. Such a ring is sometimes so symmetrically laid out as to appear artificial. It may be a few feet in diameter or even as wide across as a circus ring. A large species of mushroom, *Tricholoma praemagnum*, is common in mountain parks of Colorado where it often grows in distinct rings, sometimes 100 feet across. This is an edible species. Fairy rings start with a single mushroom plant. Its underground threads absorb all the organic food present in an area as large across as a bushel basket. The next year the threads grow outward for a distance, and a circular row of mushrooms develops, following around the region of most rapid growth. The organic matter of the soil has now been used up and growth must go still farther out. This process continues for dozens, or even scores of years. Some rings are, without doubt, over one-hundred years old.

But molds, rusts, and mushrooms are not the only Colorado fungi. More to be noticed are the lichens, so common on rocks in canyons and even on bare stony slopes exposed to wind. Then there are also lichens on the ground in moist places, and some which hang from trees; yet the commonest are the rock lichens. These are often of beautiful and striking hue,—yellow, brown, red, or gray. They contribute to the landscape many a bright or soft patch of color, especially at high altitudes where there is little other vegetation.

Lichens have a curious composition, being made up chiefly of fungous threads; but having algal cells enclosed in the meshes of the fungus. The algae make food by the process of photosynthesis just as any ordinary green plants do, that is, they capture the radiant energy of the sun and by its means are able to form sugar from the ever-present water and carbon dioxide. Such fungi as the lichens would be unable to live on rocks and tree bark if they did not have their enclosed algae to produce food for them.

The coral fungus is one of the most interesting of the general group of plants now being considered. It is two or three inches

FIG. 128. Common Liverwort (Marchantia) showing the plant with its cupules and umbrella-like female branches. A male branch from another plant is shown at left. (From Sinnott's Botany.)

tall, compact below and branched above and of waxy-white appearance. No one who has heard the name can fail to know the plant on sight.

Puff-balls are fungi of rather spherical form which sometimes appear in great numbers, coming up in a single night. They are never poisonous; in fact, all puff-balls are edible when young, before they have begun to turn yellow or brown. As they ripen, they produce great numbers of minute spores which come out with a puff when the plant is stepped on or squeezed between the fingers. The above-ground conspicuous puff-ball is only a very small part of the plant for, as is the case with mushrooms, a great network of interlacing fungal threads spreads under the surface

of the ground amid the organic materials of the soil. There are many species of puff-balls in Colorado and they are of many sizes, from that of a pea to that of an indoor baseball.

The various fungi of our flora came to Colorado, just as other plants did, from different parts of the world and at different times. No doubt, the greatest number reached North America from the Old World by way of former land connections with Asia and, spreading east and south, became distributed to this part of the Rocky Mountain region. Other fungi worked their way north from South America by way of the Isthmus of Panama, Central America, and Mexico. Besides these true immigrants, there can be no doubt that many species of fungi actually came into being within the borders of our State. Fungi show variations, just as flowering plants do; if a variant form develops from a pre-existing species, this new form may persist and multiply. It may prosper quite as well as the parent type and, in time, become established as a permanent member of the flora.

Aside from lichens, the fungi of Colorado are seldom conspicuous, for the climate is not wet enough to favor the growth of the larger kinds. Yet the total number of species of fungi is very great, especially of those which are parasites on leaves and stems of grasses and other herbaceous plants, as well as upon trees and shrubs. Hundreds of species of fungi have been collected by botanists in Colorado, probably 500 of the mushroom group alone, but a considerable part of the fungal flora has not yet been catalogued. Complete collections are needed from every part of the State in order that the facts of actual occurrence and geographical distribution be fully known. It is likely that most of our species will be found to extend for great distances through many states, that some range only in one direction, as north or east, while a few species do not grow beyond the border of the State.

The Thallophytes

The various kinds of algae, the bacteria, and the fungi are classed together as forming the lowest division or sub-kingdom of plants, the so-called thallophytes. It is convenient thus to think of them and to have a name for them but such a grouping suggests a similarity among them which does not exist. Not only do the thallophytes of Colorado differ among themselves, but other

allophytes, especially the sea-weeds, show still greater divergences in outward form and internal structure. Yet for the present, and until botanists shall agree upon a more satisfactory classification, we shall need to consider these plants as forming the first of the four divisions of which the plant kingdom is composed.

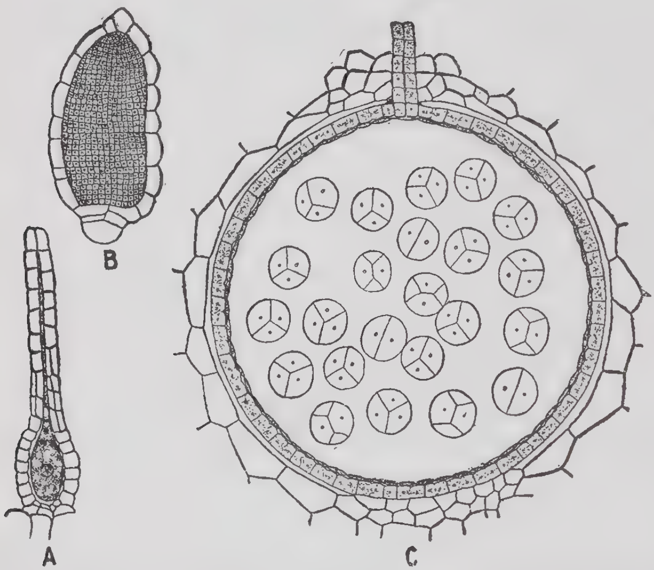


FIG. 129. Details of structure of Common Liverwort. *A*. Female Organ; *B*. Male Organ; *C*. Sporophyte (or capsule) with spores. All highly magnified. (From Sinnott's Botany.)

BRYOPHYTES

The second great group, or division of plants, is that of "mossworts", composed of the mosses and liverworts. They are known technically as bryophytes, the Greek for "moss plants". In their structure, and in their life history and reproduction, the mosses and liverworts show great likeness. They are evidently derived from alga-like ancestors which forsook the water and became established on mud or dry land. All mosses and liverworts produce dry spores which are wind-distributed. The plants are thus adapted to terrestrial life. But they require water when the eggs are to be fertilized by the sperms, for the sperms are swimming cells, suited to existence in water, in which medium alone they can make their way to the eggs. So the bryophytes usually occur in

damp places; but they are able to grow elsewhere, provided there is a rainy period at the time when they ripen their germ cells.

Since some account of the bryophytes was given in the chapter on "Plants of Streamsides and Ditchbanks" these plants need not be given full consideration now. It will be worth while, however, to point out a few of the more striking features which they present. All are relatively small; practically all live on land, but a very few occur in water; all are green in color. The mosses are leafy-stemmed plants, chiefly of erect habit. Liverworts, at least most of them, lie flat upon the ground and usually possess an irregular wrinkled or fluted body which appears somewhat like a single leaf. Certain kinds, however, are known as "leafy" liverworts because they really do have leaves. These extend in rows to the right and left of the stem.

The "common liverwort" is truly common in moist soil of Colorado, just as it is through much of the temperate zone. The horned liverwort occurs here but is seldom abundant. Leafy liverworts of various species are present, but are not often seen unless a careful search be made for them in cool, damp woods. A score or so species, all told, make up the liverwort flora of the State.

Mosses are much more numerous than liverworts, both in number of species and in number of individual plants. This is because mosses are better able to live in a dry climate than are liverworts. The number of mosses in the plains region is not great, but even in such seemingly unpromising surroundings it is nearly always possible to find a half dozen or more species. In foothill country, and in the true mountains, there are many mosses and of many kinds. Even above timberline, mosses are frequent. A day's trip to the top of a peak may yield a collection of twenty or more species, while if the sub-alpine and montane districts are also searched this number may be doubled.

It is much to be desired that full collections of mosses and liverworts be made in all parts of the State. These plants have received little attention as yet from either amateur naturalists or professional botanists. One reason for this is the difficulty of their study due to the small size of the plants, and the minute features which must be observed if an attempt is made to classify them. Few botanists have any acquaintance with mosses; when

they wish to know something about a particular kind of moss they send it to a "bryologist", as a moss-specialist is called. Mosses and liverworts are much the same over large areas of territory so it is not likely that many hitherto undescribed species will be found, yet it would be interesting to know what species occur within the State, and in what localities.

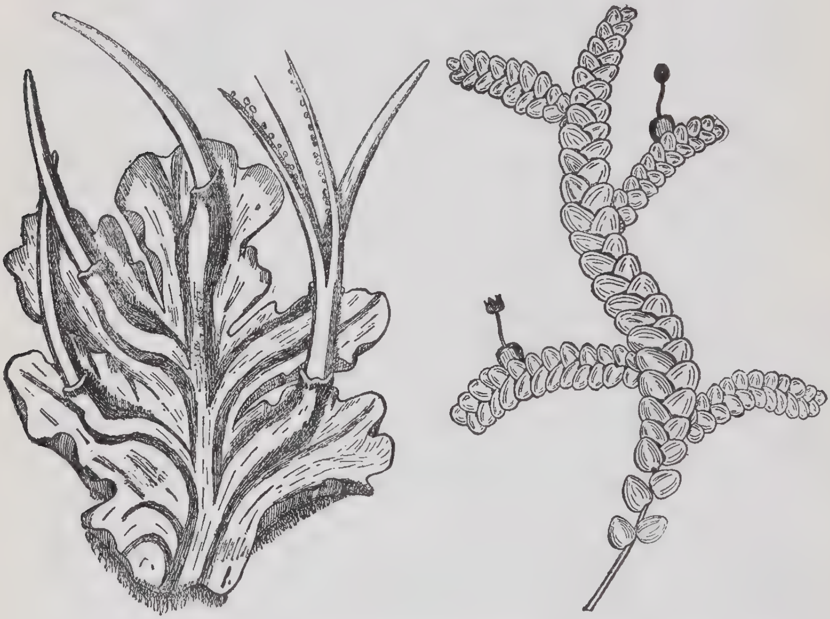


FIG. 130. Liverworts. At left, the Horned Liverwort. At right, a Leafy Liverwort. (From Sinnott's Botany.)

PTERIDOPHYTES OF COLORADO

The fernworts or pteridophytes (Greek, "fern plants") make up the third division of the kingdom of plants. They are of much more complicated structure than the mosses or liverworts, and they reach a greater size. In Colorado, at the present time, there are representatives of three classes of this plant-group. These are: (a) the ferns, with 30 species, (b) the clubmosses, with five species, (c) the horsetails, with three species. All of these plants reproduce by spores, as do the bryophytes, and all of them require water for the fertilization of their eggs, since the sperms are swimming-cells.

FERNS

Although there are 30 species of ferns in the State, they are rare or infrequent. Dryness of the air is a condition not at all suited to ferns. Many kinds can flourish with little rainfall, but they require at least moderate humidity of the air. Ferns in Colorado are chiefly confined to narrow canyons or to cracks between rocks. In some few sub-alpine stations they reach a certain luxuriance, as they do occasionally among large rocks in narrow straight-walled gorges of the foothill country.

The commonest ferns are small ones: species of Woodsia and Filix. Larger and more conspicuous, but rather locally distributed are the bracken, lady-fern, and male fern. One of the handsomest of our species is the beautiful holly fern of high altitudes, seldom seen in Colorado east of the Continental Divide, although it grows in Northern Michigan and as far east as Nova Scotia.

Ferns show a definite "alternation of generations" in their life history. The ordinary fern plant produces spores which arise in the familiar brown "fruit dots" on the backs of the leaves. The spores, when ripe, are scattered, and then germinate on moist soil where they give rise to small, flat green plants scarcely larger than a moss leaf. Each of these plants bears the male and female organs and thus forms both eggs and sperms. When the sex cells (gametes) are ripe, the sperms swim to the egg organs, if water is present. After a sperm makes its way to the egg within an egg organ, the egg and sperm unite. From the fertilized egg which has been thus formed the true fern plant eventually grows. In order that the two generations may be distinguished by name, the ordinary fern plant is called the sporophyte (spore-bearing plant) while the very small plant, no larger than a moss leaf, is called the gametophyte (gamete-bearing plant.) The alternation of generations consists in this, that a fern plant, or sporophyte, produces spores which give rise to the tiny gametophyte; then the gametophyte produces gametes, that is, sex cells, and these give origin to the sporophyte once more.

CLUBMOSSES

Clubmosses are represented in our flora by one species of "ground pine" or lycopodium, which grows in moist spruce forests, and by four sorts of the smaller clubmosses, or selaginella. All of

these plants are somewhat moss-like in appearance, although much less delicate in structure. Since florists use the name lycopodium for any kind of clubmoss, it is likely that most readers would be inclined to do the same. There are, however, interest-

FIG. 131. Mosses. At left, the Hair-cap Moss. At right, Peat Moss (Sphagnum). (From Sinnott's Botany.)

ing differences between the two types of clubmosses. Most important of these differences is the production of two sizes of spores by the selaginellas and of only one kind by the lycopodiums. The spores in both are borne on scale-leaves which form little cone-like structures; these look something like clubs, whence the name,

"clubmoss". Selaginella has a course of development and reproduction very much like that of the seed plants, but the story is a long one and can not be told here.

There is very little lycopodium in Colorado in comparison to its abundance in the pine woods of Wisconsin and Michigan. So these materials for Christmas wreaths and festoons must be imported. As for the smaller clubmosses, they are common enough, chiefly on barren slopes in the foothill and montane districts, some also as high as timberline. They are, however, very dwarf, being only an inch high, and not greatly spreading; hence they are of no decorative value.

HORSETAILS

The horsetails, or scouring rushes, belonging to the genus *Equisetum*, are a small remnant of a once important group of plants. They are confined chiefly to low ground, especially where the soil is of sandy nature. In their manner of reproduction they are like the common ferns, for they produce spores all of one kind; these grow into minute liverwort-like plants which bear the male and female organs. The sperms are swimming-cells which reach the egg organs when rain or dew is present. After the egg is fertilized it gives rise to the ordinary horsetail plant.

PTERIDOPHYTES OF COLORADO IN FORMER GEOLOGIC TIMES

In Mesozoic times the pteridophytes formed a much more important part of the plant population than they do now. As already stated in the chapter on "Forests and Forest Trees", there were present in Colorado the scale trees, which were gigantic clubmosses. Ferns were abundant and were much concerned in the production of coal. Horsetails also existed in great numbers, and attained to larger size than those of the present day. There were other genera of horsetails, somewhat different from the genus Equisetum of today.

SPERMATOPHYTES, SEED PLANTS

The seed plants make up the fourth, and highest, division of the plant kingdom. They are technically known as spermatophytes (Greek, "seed plants"). They are the plants which are best known because of their size, their abundance, and their economic importance. All field and garden plants, as well as orchard and forest trees are spermatophytes.

The chief difference in spermatophytes are best indicated in a tabular comparison.

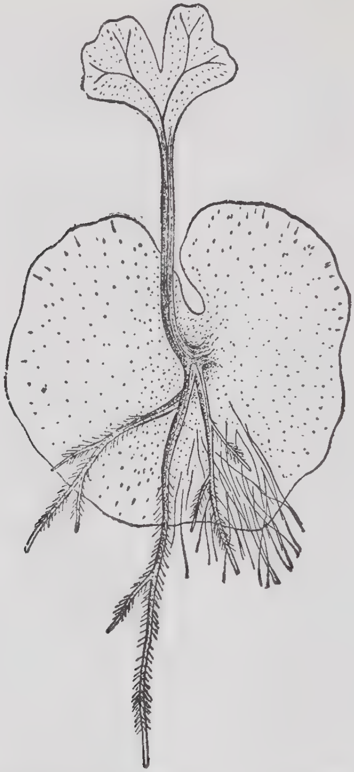


FIG. 132. Fern Prothallus, or gametophyte, with young fern plant (sporophyte) growing from it. (From Sinnott's Botany.)

CLASSIFICATION OF SPERMATOPHYTES

1. GYMNOSPERMS. The seeds are attached to dry (sometimes fleshy) cone-scales, but are never borne in a true ovary. Flowers are not conspicuous. Examples: pine, fir, spruces, cedar, juniper, joint-fir. The word "gymnosperm" means literally "naked seeds". In Colorado, there are 20 species.

2. ANGIOSPERMS. The seeds are borne in an ovary; flowers often, but not always, conspicuous. The word "angiosperm" suggests that the seeds are enclosed in a sac, the ovary.

   a. *Dicotyledons.* Two seed-leaves, or cotyledons are present; stems have a single ring of vascular bundles; leaves are usually netted veined. Examples: oak, maple, ash, rose, buttercup, evening-primrose, poppy, sunflower, aster. In Colorado, there are about 2,500 species.

b. *Monocotyledons*. There is a single cotyledon, which is not leaf-like. It serves merely as an organ of absorption to get the food from the endosperm into the plantlet during early growth. Stems have more than one circle of vascular bundles; the bundles, appear to be irregularly scattered. Leaves are often parallel veined. Examples: lilies, grasses, sedges, rushes, irids, orchids. The number of species of monocotyledons in Colorado is about 500.

THE GYMNOSPERMS

Gymnosperms are an ancient group of plants which formed the dominant vegetation of large parts of the earth through long geologic periods. In Mesozoic times the species in Colorado were many and varied. Later, in the Miocene, there were pines, redwoods, and probably other gymnospermous trees. Even today, when there are many other trees crowding upon them, the pines, spruces, and firs still form great forests within the State.

The gymnosperms have been considered from time to time in some of the preceding chapters, especially in "Forests and Forest Trees". Further descriptions are given in the "Keys to Colorado Trees" which form a part of Appendix I.

THE ANGIOSPERMS

The angiosperms embrace two classes of plants (dicotyledons and monocotyledons). They reproduce by true flowers, and they form their seeds in definite closed ovaries which become the fruits. It is apparent that both groups are "higher" than the gymnosperms, and they are usually referred to as the "higher seed plants", but the relative standing of the two groups themselves is somewhat doubtful. There are some simple and apparently primitive plants among both the dicotyledons and monocotyledons. It is a question of interest then as to which group was the earlier in development on the earth. This is hardly the place to argue the point, and so it may be stated that the monocotyledons are thought to have developed as an offshoot of early dicotyledons. Monocotyledons are rather conservative, keeping to a fairly constant structure. They do not exhibit great variety in appearance nor complexity of flower-structure nor in their cellular architecture. The lilies, amaryllids, and irids are typical families. There is another family, however, namely the orchids, the members of which are very remarkable for their flowers. These show marvelous mechanisms for securing insect visits, and consequent cross pollination. Yet the orchid family, even though

its members do have these wonderful structures, can not be considered successful in comparison with some of the higher families of the dicotyledons. True, the family includes very many species all over the world but the orchids are nowhere numerous. They are too highly specialized themselves and they require very highly specialized environments. Like narrow specialists among men in the industrial world they find few satisfactory niches. In Colorado, there are not many species of orchids and they are rare, represented by few plants.

FIG. 133. Some examples of Pteridophytes. *A.* A kind of Fern (Woodsia); *B.* Small Clubmoss (Selaginella); *C.* Large Clubmoss (Lycopodium); *D.* Horsetail (Equisetum), vegetative shoot; *E.* Horsetail, reproductive shoot.

MONOCOTYLEDONS OF COLORADO

The 500 species of monocotyledons of Colorado are included in about 18 families, but most of these are not well known except to professional botanists. The grasses and sedges, however, form an important part of the vegetation. Certain other families of

monocotyledons, as the palms, occur in warmer parts of the world and do not grow here except with cultivation under glass. Seven of the more conspicuous or interesting families are listed below:

Some Families of Monocotyledons in Colorado

Cat-tail family: only one genus in the State, one species.
Grass family: the grasses; 70 genera and 267 species.
Sedge family: the sedges; eight genera and 101 species.
Rush family: two genera, 27 species.
Lily family: 15 genera, 36 species.
Iris family: two genera, five species.
Orchid family: 12 genera, 24 species.

Dicotyledons of Colorado

The 2,350 species of dicotyledons of Colorado belong to 547 genera, in 100 families. Among dicotyledons with simple flowers are many of the common trees, as willow, cottonwood, alder, birch, and oak. More highly organized flowers occur in the crowfoot family, but even these are considered rather primitive. Examples of flowers of moderately high type are the pinks, roses, and peas; while among those which have departed very far indeed from the simple and primitive in structure may be named the parsley, figwort, bellflower, and thistle families.

A dozen of the more interesting families of dicotyledons may be listed in order of complexity.

Some Families of Dicotyledons in Colorado

Willow family: the willows and poplars; two genera, 33 species.
Crowfoot family: buttercups, columbines, marsh marigold; 17 genera, 92 species.
Pink family: pinks and chickweeds; 10 genera, 55 species.
Mustard family: mustard, cress; 27 genera, 144 species.
Rose family: rose, cinquefoil; 21 genera, 89 species.
Pea family: peas, beans, vetches; 36 genera, 185 species.
Cactus family: prickly pear, ball cactus; four genera, 23 species.
Parsley family: wild parsley, wild carrot, parsnip; 27 genera, 58 species.
Gentian family: gentians; nine genera, 27 species.
Phlox family: phlox and gilia; nine genera, 58 species.
Figwort family: beard-tongue, Indian paint-brush, lousewort, little-red-elephant; 18 genera, 106 species.
Thistle family: thistle, goldenrod, aster, sunflower; 88 genera, 586 species.

History of the Study of Colorado Botany

The plants of Colorado have become recognized through the work of many collectors and describers. So far as is known, the first botanist to enter the area now included in the State of Colorado, was Edwin James, who served as historian and naturalist of

Major Long's Expedition (1819-20). His collections were made chiefly in the foothills and mountains from Platte Canyon southward. It is for him that James Peak is named. The wild mock orange, has been called *Jamesia* or *Edwinia*.

After the visit of James there were, probably occasional plant specimens collected by travelers but no systematic collections were made until the time of the later exploring expeditions conducted under authority of the Federal Government. John C. Fremont's expeditions (1842-45) were the first of these; about ten years later came the surveys for a Pacific railway. Plants of these collections were described by the botanists John Torrey and Asa Gray. In 1861, and at various times during the following ten years, collections were made by Charles C. Parry in Colorado. Parry was an able and enthusiastic collector. The beautiful Parry primrose of high altitudes commemorates in its name this most active naturalist. Many of his plants, as well as those of Hall and Harbour collected at the same period, were described by Asa Gray.

About the time of Parry a number of botanists worked upon the Colorado flora, especially Professor Thomas C. Porter of Easton, Pennsylvania, George Engelmann of St. Louis, and J. T. Rothrock of Pennsylvania. Their papers appeared chiefly in government publications, while Asa Gray's work came out partly in these official documents and partly in the American Journal of Science and other periodicals.

The First Resident Botanist of Colorado

So far as known to the present writer, the first resident botanist of Colorado was Edward Lee Greene who came to the State in 1870. He lived at first in Pueblo and later was for a time pastor of a church at Golden. During his residence here, and for many years thereafter, while in California, he continued to describe species of the flowering plants of this State. The later years of his life were spent in Washington, D. C. where he kept up his botanical studies until the time of his death in 1915.

Botanical Activity in the Seventh and Eighth Decades of the Nineteenth Century

The decade from 1870 to 1879 saw a great outburst of botanical activity for, besides the work of Dr. Greene, there was that

of Townsend S. Brandegee, Thomas C. Porter, and John M. Coulter. All of these published accounts of new species and all made extensive collections. Various other collectors, perhaps a dozen in number, were also in the field at different times.

Mr. Brandegee was a civil engineer who studied at first the flora around Canon City and afterward that of Southwestern Colorado. At a later time he moved to California, where for many years he was associated with the University of California, at Berkeley. His early collections were largely named by Asa Gray.

The first connected account of the plants of Colorado was the "Synopsis of the Flora of Colorado" by Thomas C. Porter and John M. Coulter, published in 1874 in the Miscellaneous Collections of the U. S. Geological and Geographical Survey of the Territories. The work consists of 180 pages devoted to lists and descriptions of all plants known at that time from the Territory of Colorado. There are 150 pages given to the seed plants, two pages to the fernworts, six to the mosses, and four to the lichens and fungi. A total of about 1500 seed plants was recorded. Professor Porter states in his letter to the Geologist in charge of the Survey that:

> The work is based chiefly on collections made, in 1861 and succeding years by Dr. C. C. Parry, whose indefatigable labors have added so much to our knowledge of the flora of the region; in 1862, by Messrs. Hall and Harbour; in 1867 by Dr. W. A. Bell of Manitou Springs; in 1868, by Dr. F. V. Hayden; in 1869, by B. H. Smith, Esq., of Denver; in 1871 by Dr. George Smith and W. M. Canby, Esq.; in 1871 and 1873 by Messrs. Meehan and Hooper; in 1872 by J. H. Redfield, Esq.; in 1872 and 1873, by T. S. Brandegee, Esq. of Canon City, Rev. E. L. Greene of Pueblo, and T. C. Porter; and in 1873 by J. M. Coulter.

Professor Marcus E. Jones was one of the early botanists resident in the State. In 1879 he was head of the science department of Colorado College. During 1878 he collected and distributed many sets of herbarium specimens of Colorado plants. In 1880 he moved to Salt Lake City where for over forty years he kept up his botanical work.

Miss Alice Eastwood was teacher of Botany in the Denver High School from 1880 to 1890. She made many collections and distributed these to various herbaria. She prepared a Flora of

Denver and vicinity which was published in San Francisco after her removal to that city.

In 1881, Mr. J. I. McFarland, a member of the first class at the University of Colorado, made extensive collections in Boulder County. His beautifully prepared specimens formed the nucleus of the herbarium of the University. Mr. McFarland died at an early age and science was deprived of a very promising worker.

In 1884 the Manual of Rocky Mountain Botany by John M. Coulter was published, and soon became known as "Coulter's Manual". It was for many years the only work by means of which collectors could determine their plants. Its publication was the most important single feature of the botanical history of the State during the period from 1880 to 1889.

Theodore D. A. Cockerell, now of the University of Colorado, was a resident of Colorado during 1887-90, during which period he became acquainted with the flora and fauna. After 13 years absence, he returned in 1903 and, although giving most of his time to zoology, continued also his interest in botany. He has worked largely with fossil plants.

Resident Botanists from 1890 to 1900

During the ten years from 1890 to 1900 the following botanists settled in Colorado: Ellsworth Bethel (1890), C. S. Crandall (1890), Francis Ramaley (1898). The first-named, traveled to all parts of the State and came to know its flora in the field better than any man since the time of Parry. His death occurred in 1925. Professor Crandall of the Colorado Agricultural College made collections from 1880 to 1900. Mr. George E. Osterhout became a resident of Windsor, Colorado in 1886 and began collecting plants in 1892; ever since that time he has been an active non-professional student of plants. Professor Carl F. Baker, for a time with the Colorado Agricultural College, at Ft. Collins, made important collections in the southwestern part of the State from 1896 to 1901. Mr. D. M. Andrews, at first a plant collector and later a nurseryman and horticulturist came to Boulder in 1893 and has done much to introduce native shrubs into cultivation.

PROFESSOR AVEN NELSON

About the middle of the decade 1890-1900, Professor Aven Nelson, who in 1887 had become Professor of Botany at the University of Wyoming, began an intensive study of the Rocky Mountain flora, collecting, distributing, and naming plants of Wyoming, Colorado, and adjacent states. In 1909 he published, with Professor Coulter, a revision of Coulter's Manual of Rocky Mountain Botany.

DR. PER AXEL RYDBERG

Another botanist, Per Axel Rydberg, who has done much for Colorado botany, gathered specimens in the summer of 1890. He came again in 1891 and still later in 1895. Ten years after this last-mentioned visit he published, as a bulletin of the Agricultural Experiment Station of the Colorado Agricultural College, the important "Flora of Colorado", and in 1917 the "Flora of the Rocky Mountains and Adjacent Plains".

OTHER STUDENTS OF COLORADO PLANTS

In all, probably more than 100 botanists have made collections in Colorado. Almost as many have prepared the original descriptions for some of the plants collected by themselves or others.

In recent years, much of the writing concerning Colorado plants has dealt with vegetation studies, rather than with description of individual plants. Dr. Frederic E. Clements began, in 1896, to spend his summers in the mountains near Colorado Springs, and there engaged in important ecological investigations which have been continued by him and by his students and associates to the present time. Homer L. Shantz and Edward C. Schneider made studies in the same part of the State. Professor J. E. Weaver of the University of Nebraska has carried on work upon the root systems of plants at various points in the eastern and southern parts of Colorado.

Ecological work in the present century by persons in some way connected with the University of Colorado, is reported in the writings of Robert T. Young, W. W. Robbins, Katharine Bruderlin, Helen A. Leonard, Arthur G. Vestal, Ed. L. Reed, L. O. Overholts, Arthur C. McIntosh, Hazel Schmoll, and the

present writer. A list of papers dealing with Colorado vegetation studies is given in Appendix III to this book.

The Future of Botanical Study in Colorado

For a full understanding of the flora of Colorado much more remains to be done. We need to know the lower plants; we need to know the fossil plants; we need to know the ecological relations of plants. There is work for the amateur and for the professional botanist—no end of work, for those who wish to press into the unknown and thus extend the boundaries of knowledge.

Appendix I

KEYS TO COLORADO TREES

It is possible to identify the trees of Colorado by means of suitable keys. A "key", as understood by a botanist, consists of descriptive phrases so arranged that certain alternatives are presented to the reader who, in making proper choices, discovers the name of the tree or other plant in which he is interested.

The Key to Genera of Native Colorado Evergreens below may be taken as typical. When one learns how to use it there should be no difficulty with other similar keys. Let us suppose that we are in a forest seated by an evergreen tree the name of which we wish to learn. We are to read first the two alternatives I and II of the key, and decide which of them applies to the tree we are studying. If our tree has needle-like foliage and if the fruit is a cone it must fall under I, and be a member of the Pine Family. Next we read A and B, deciding to which our tree belongs. If it belongs to B the next choice is between "c" and "d". If the paragraph "c" describes it then we know that the tree is a spruce, of the genus Picea. This may be all we care to know about it, but if we wish to learn which particular kind of spruce it is, a key to species of Picea must next be consulted. (See page 279.)

If the tree to be identified is deciduous instead of evergreen the key on page 282 is to be used.

Key to Genera of Native Colorado Evergreens

I. Trees with needle-like foliage, fruit a cone; Pine Family.

- A. Leaves (needles) usually more than 25 mm. (1 in.); two or more in a bundle and surrounded at the base by a short sheath; the cones when mature hard and woody (the pines) — Genus 1. Pinus, p. 278
- B. Leaves about 25 mm. long, or less; single, not in bundles; the cones rather papery or leathery
  - c. Leaves with a short brown woody base which remains attached to the twig after the leaf has fallen; the leaves stiff and four-angled, not flat (the true spruces) — Genus 2. Picea, p. 279
  - d. Leaves not brown, nor woody at base, green throughout; flexible, flat; when they fall they drop completely and leave a depressed scar
    - e. Leaves quite soft; narrowed toward the base into a very short leaf-stalk which broadens slightly at the point of attachment; cones hanging down, having numerous three-pointed projecting bracts (the Douglas spruce) — Genus 3. Pseudotsuga, p. 280
    - f. Leaves moderately soft, only slightly narrowed at base; leaf-scars circular in outline; cones erect (the firs) — Genus 4. Abies, p. 281

II. Trees and shrubs with small flat, somewhat scale-like green leaves; fruit a berry; Juniper Family.

- G. Straggling shrub, or a small tree with rather stiff and sharp leaves; — Genus 5. Juniperus, p. 282
- H. Usually small trees, often dense and of symmetrical form with minute over-lapping, rounded scale-like leaves (the cedars) but not the cedar of the Old World — Genus 6. Sabina, p. 282

DESCRIPTIONS AND KEYS TO SPECIES

Genus I. PINUS, PINE

Evergreen trees and shrubs growing often in dry and rocky situations. Foliage leaves needle-shaped growing usually in bundles of two to five leaves. The foliage leaves are borne on very short twigs (dwarf shoots), which arise in the axils of appressed scale leaves. Staminate cones small, yellow or reddish, growing in clusters and shedding their pollen in late spring or early summer. Carpellate cones either solitary or clustered. Cone scales thick, becoming woody. The cones ripen the second year or later.

I. Leaves in bundles of 4 to 6; trees chiefly of high altitudes

A. Leaves 25 to 40 mm. (1-1½ in.) long. Cones 7-9 cm. (2½-3½ in.) long, the scales with curved, needle-pointed spines *Pinus aristata*

B. Leaves 3.5 to 7.5 cm. (1½-3 in.) long. Cones large, 7-25 cm. (2¾-9¾ in.) long; the scales smooth, without spines *Pinus flexilis*

II. Leaves in bundles of 2 or 3

C. Leaves short, 2 to 4 cm.(¾ to 1½ in.) long, generally in pairs, cones small, about same length as leaves; seeds large. Tree of foothills, mesas, and river bluffs *Pinus edulis*

D. Leaves longer, 4 to 6 cm. (1½ to 4¾ in.); in bundles of 2 or 3

E. Leaves usually about 10 cm. (4 in.) long but often shorter or longer. Cones 6 to 9 cm. (2¼ to 3½ in.) long. Large tree, from plains region to altitudes of about 10,000 feet. *Pinus scopulorum*

F. Leaves 3 to 6 cm. (1¼ to 2½ in.) long; cones about same length as leaves. A medium-sized tree of foothills and mountains *Pinus murrayana*

Pinus aristata, Bristle Cone Pine. Leaves in bundles of four or five, dark green, 2.5 to 4 cm. long. Cone 7 to 9 cm. long. Cone scales somewhat thin, each with a slender curved bristle about 6 mm. long. Seeds winged.

A bushy tree of small or medium size with the main trunk short, numerous strong branches starting rather low down. Bark thin, pale or milky white on small branchlets, dark gray or brown on the main trunk. Wood soft and not durable; specific gravity 0.5572.

Rocky and gravelly slopes at high altitudes in the mountains from James Peak to southern Colorado, Utah, Nevada, southern California, and Arizona.

Pinus flexilis, Limber Pine, White Pine. Leaves in bundles of five; stout, rigid, dark green, 3.5 to 7.5 cm. long. Cone very large, 7 to 25 cm. long. Cone scales smooth, without bristle points. Seeds large, with a narrow wing which usually adheres to the cone scale when the seeds drop.

A medium-sized tree with a short main trunk and abundant lateral branches, growing in wind-swept situations and hence often much distorted. Bark of twigs and branches pale gray or whitish, becoming dark brown on older trunks. Wood light, specific gravity 0.4358; sometimes used for lumber which is, however, full of knots.

Eastern slope of Rocky Mountains from Alberta to western Texas, westward through Montana to Nevada and California. It is the principal tree of the upper foothills of the eastern slope in Montana. In Nevada it forms extensive forests. In Colorado and Wyoming it is usually scattered in exposed situations at rather high altitudes but a few trees are found on the bluffs west of Pawnee Buttes, Colo., at an altitude of 5,000 feet.

Pinus edulis, Pinyon, Nut Pine. Leaves in bundles of two, rarely three; dark green, curved, stiff, 2 to 4 cm. long. Cone when mature about the same length as the leaves and nearly spherical; cone scales few, thick, spiny tipped. Seeds large, about the size of a small white bean, the narrow wing of the seed remaining adherent to the cone scale when the seed falls.

A small or medium-sized tree, much branched and shrublike. Bark rather thin; that of young branchlets orange colored, becoming at length gray or brown. Wood rather durable; specific gravity 0.6388; brittle, close grained. Used for fuel and fencing and sometimes for preparation of charcoal. In western Texas it has been sawed for lumber. The large, edible seeds, known as "pinyon nuts", collected by Indians, are on sale by fruit dealers in the towns and cities of Colorado.

Eastern foothills of the outer range of the Rocky Mountains from near the Palmer Lake divide south to western Texas and west to Arizona and southwestern Wyoming. In places it forms open forests with the rock pine; mixed with cedars it is common on the hills and table lands of western Colorado. It does not extend to very high altitudes.

Pinus scopulorum, Rock Pine. Leaves in bundles of two or three, variable as to number even on the same tree; stout, dark yellowish-green, often in bottle-brush arrangement at the ends of naked branches; 8 to 15 cm. long. Cone 6 to 9 cm. long, the cone scales each with a stout, sharp prickle. The young cones are erect the first summer, when fully grown they are horizontal or slightly declining.

A handsome spreading tree, the largest of our pines, with thick, deeply-furrowed, reddish bark becoming very thick on old trees. Wood hard and strong but differing greatly in quality; where abundant it is sawed into lumber or used for railway ties and mine timbers. The specific gravity is 0.4619.

Hills and ridges of western Nebraska to Rocky Mountain region and from Montana to Arizona and New Mexico.

On account of its resistance to drought this tree should be a valuable one for planting in semi-arid districts. The large seeds germinate freely and the trees are easily grown when given reasonable care. Sometimes called "yellow pine" or "blackjack".

Pinus murrayana, Lodgepole Pine. Leaves in bundles of two, yellow-green, 3 to 6 cm. long. Cone about the same length as the leaves, very persistent, often remaining attached three or four years after ripening; cone scales with short, sharp prickles.

A tall, straight tree, generally growing in dense groves on north slopes in the higher foothills. The trees have been considered of little value for lumber but they are certainly most useful in holding the soil and in protecting snow from too rapid melting. Seeds of this pine, unlike those of most species, retain their vitality for a number of years. Burned districts become re-seeded by the opening of the cones which takes place on account of the heat produced by the fire. Wood rather light and soft, not durable; specific gravity 0.4096. Used to some extent for ties, mine timber and fuel when better wood is not available. Recently developed methods of seasoning and preservative treatment promise to make the lodgepole pine valuable for railway ties and mine timbers.

Montana to southern Colorado, west to California and Alaska. In the higher foothills and the montane zone of Colorado.

Genus 2. PICEA, The True Spruces

Tall, conical, evergreen trees with tapering trunk and thin, scaly bark. Leaves needle-shaped, four-angled or flattened (ours four-angled) with sharp points. The leaves extend out from all sides of the twig in bottle-brush

fashion; they are not in bundles as in pine but occur singly. Leaves jointed near the base, the lower part (sterigma) becoming woody and persistent after the fall of the leaf. Bare twigs thus appear roughened with short, truncate elevations. Cones pendant, chiefly on the upper branches.

IA. Leaves rigid, needle-pointed, blue-green or silvery, branchlets smooth or at least not hairy. Cones about 7 cm. (2¾ in.) long. Frequent in cultivation. *Picea parryana* (or *Picea pungens*)

IB. Leaves less rigid, abruptly pointed, having a somewhat skunk-like odor when bruised. The branchlets are generally described as pubescent but are smooth in specimens grown at high altitudes. Cones about 4 cm. (1⅝ in.) long. *Picea engelmanni*

Picea parryana, Colorado Blue Spruce. Leaves stout, rigid, four-angled, mostly 25 to 30 mm. long but on cone-bearing branches shorter and curved. Generally the leaves stand out from all sides of the branchlets but sometimes the under surface of horizontal branches has few leaves. Color of leaves generally silvery or bluish-green when young, becoming duller with age. Individual specimens differ greatly in this regard. Cones about 7 cm. long.

A tree of medium size. Bark broken into small oblong, platelike scales; on old trunks thick and deeply grooved. Wood light, soft, weak; specific gravity 0.3740.

Along the mountain streams of central Colorado, west to Utah and north to the Wind River Mountains of Wyoming, occurring singly or in small groves.

Much cultivated for ornament in this country and in Europe. There are numerous horticultural varieties propagated by grafting.

Picea engelmanni, Engelmann Spruce. Leaves ridged above and below so that they are rather four-sided; awl pointed; not so stiff as those of the blue spruce. Leaves at first covered with a bluish or silvery bloom which disappears later; slender, 25 to 30 mm. long on the ordinary branches but shorter on cone-bearing twigs. Cones 3 to 5 cm. long.

A large conical tree of the higher foothills and mountains; near timber limit a straggling, prostrate shrub. Bark thin, broken into large, thin, loose scales. Wood light, soft, close grained, not strong; specific gravity 0.3449. Frequently used for lumber and for making charcoal. The bark has been employed for tanning leather. In some localities the Engelmann spruce has been largely cut for railway ties and to some extent for telegraph and telephone poles. It should be valuable for wood pulp.

In the Cascade, Selkirk and Rocky Mountain ranges of British Columbia and Alberta, south through the mountain states to New Mexico and Arizona, west to Oregon. It is by far the more abundant of our two species of *Picea* and is the common tree near timberline where it forms scrubby mats. In such situations it seldom bears cones. At 10,000 to 11,000 feet altitude it reaches its largest size.

The Engelmann spruce has been planted for ornament in the eastern United States and in Europe. Sometimes it is mistaken for the blue spruce. These two species of *Picea* are not easily distinguished; however, the size of the cones is a marked feature.

Genus 3. PSEUDOTSUGA, DOUGLAS SPRUCE, DOUGLAS FIR

Tall conical trees with thick, furrowed bark and strong wood resembling in quality the best of hard pine. Branches generally ascending, the branchlets spreading; general appearance more feathery than true spruce. Leaves linear, flat, narrowed at base to a short leaf-stalk. Cones pendant; usually

scattered over the tree; not confined to the upper branches; cone scales persistent; bracts with prominent teeth giving the cone a fringed appearance. Three species of this genus are known; one in Japan, two in western North America.

Pseudotsuga taxifolia,* Douglas Spruce, Douglas Fir. Leaves rather soft, not rigid, flat, channeled above and ridged below, 20 to 35 mm. long, dark yellow-green in color, narrowed to a short stalk; leaf scars not prominent. Cones pendulous, 5 to 10 cm. long, the bracts projecting beyond the scales. Each bract with two lateral teeth and the midrib projected as a rigid awn.

A tree of handsome conical form, especially when young; reaching the greatest size in the moist forests of Oregon and Washington. Bark on young trees smooth and thin; on older trees very thick and deeply furrowed. Wood hard; light red or yellow; specific gravity 0.5157; largely manufactured into lumber in the Pacific Northwest where it is generally known as "Oregon pine", "Douglas fir" and "red fir". Employed for fuel, railway ties and piles; in Colorado used as Christmas trees.

British Columbia and Alberta southward through hills and mountains to northern Mexico and western Texas.

Frequently planted as an ornamental and shade tree in Europe and the eastern United States. Numerous varieties are distinguished in cultivation.

Genus 4. ABIES, THE FIRS, BALSAMS

Tall conical trees of colder regions and mountain districts. Leaves linear, flat, sessile; grooved above and having a notched apex. On the upper cone-bearing branches the leaves are often curved and thick, with the upper surface convex instead of grooved. Cones erect; purplish-black or yellow, formed of closely overlapping scales; exuding a balsamic resin. The cone-scales and bracts separate from the axis while this is still on the tree; hence complete cones are never found under the trees.

1A. Leaves of vigorous lower branches 2.5 to 4.5 cm. (1 to 1¾ in.) long; resin ducts of the leaves deeply imbedded, not close to the epidermis. Cones purple or nearly black. *Abies lasiocarpa*

1B. Leaves of vigorous lower branches 4.5 to 7.5 cm. (1¾ to 3 in.) long; resin ducts of the leaves close to the epidermis of the under surface; cones yellow, green or purple. Not found in northern Colorado. *Abies concolor*

Abies lasiocarpa, Sub-alpine Fir. Leaves flat, with prominent mid-vein, bluish-green; on vigorous lower branches 2.5 to 4.5 cm. long; on old parts and on cone-bearing twigs much shorter. Cone oblong-cylindrical, rounded, erect, purple or nearly black, 6 to 10 cm. long.

A medium sized tree with branches extending nearly to the base of the trunk; bark of young trees pale gray and smooth; on old trees broken with shallow fissures and roughened with thin orange-colored scales. Wood light, not strong, nor durable; of little value but sometimes used as firewood; specific gravity 0.3476.

High altitudes in the mountains throughout western North America.

Abies concolor, White Fir. Leaves mostly in two rows on the branchlets, more or less erect; on lower branches flat, straight, with rounded or pointed apex; length 4.5 to 7.5 cm.; on cone-bearing twigs shorter and generally curved. Cone ellipsoid-cylindrical, 7 to 13 cm. long, grayish-green, purple or yellow, with broad, closely imbricated scales. A large tree with narrow

*Known also as Pseudotsuga mucronata.

spire-like crown; the short, main branches bearing long, lateral branchlets; the whole forming frond-like masses of foliage. Bark of old trunks becoming very thick, deeply divided into broad, rounded ridges. Wood light, close grained, not strong nor durable; specific gravity 0.3638.

From the Pike's Peak region of the Rocky Mountains of Colorado west to Oregon and south to northern Mexico and Arizona, reaching its greatest development in the Sierras of California. It is the only true fir in the arid regions of the Great Basin.

Genus 5. JUNIPERUS, JUNIPER

This genus, as here limited, has two species in Colorado. The common low-growing shrubby species is ***Juniperus sibirica.***

IA. Very low shrub with sharp acute leaves. ***Juniperus sibirica***

IB. Erect shrub or small tree with more acuminate leaves ***Juniperus communis***

Genus 6. SABINA, CEDAR

The trees and shrubs of this genus are often classified with the junipers and placed in the genus *Juniperus*. It seems best to separate them because the cedars have such a very different general appearance. Leaves of true junipers are sharp-pointed and awl-shaped; instead of being scale-like and rather soft to the touch, as are the leaves of cedars. It is to be noted, however, that the leaves of young cedars are sharp-pointed and look like the leaves of junipers.

IA. Fruit when ripe, blue, juicy, resinous.

- 2c. Leaves with minute teeth near the apex; fruit generally one-seeded. ***Sabina monosperma***
- 2d. Leaves entire at apex; fruit generally several-seeded. The common cedar of the eastern slope in Colorado. ***Sabina scopulorum***

IB. Fruit when ripe, reddish-brown, dry, fibrous. Small tree of western Colorado and westward. ***Sabina utahensis***

KEY TO GENERA OF NATIVE DECIDUOUS TREES

I. Trees with simple leaves, not composed of leaflets

- A. Leaves usually at least three times as long as broad; bark rough and of bitter taste; flowers and fruits in erect catkins (willows) Genus 8. Salix
- B. Leaves not greatly elongated; (except narrowleaf cottonwood) other characters also different from A
  - a. Flowers and fruits in drooping catkins; seeds cottony; branches and twigs white or light gray (cottonwoods, aspen, poplars) Genus 7. Populus
  - b. Flowers and fruits not usually in catkins but if so, the seeds are not cottony
    - c. Leaves with palmate veining, the main veins extending from the base of the leaf-blade like fingers from the palm of the hand (maple) Genus 18. Acer
    - d. Leaves with pinnate veining, the main veins extending out on both sides of a central mid-rib

e. Twigs thorny
  ee. Thorns sharp, numerous (thornapple, hawthorn) Genus 15. Crataegus
  ff. Thorns few, usually blunt (plum) Genus 16. Prunus

f. Twigs without thorns
  g. Trees with conspicuous flowers and fleshy fruits
    gg. Trees evenly toothed all around the margin (cherry, plum) Genus 16. Prunus
    hh. Leaves toothed chiefly near apex (Juneberry) Genus 14. Amelanchier
  h. Trees not having conspicuous flowers or fleshy fruits
    i. Leaves pinnately lobed; the lobes and sinuses rounded; fruit an acorn (oaks) Genus 11. Quercus
    j. Leaves not lobed, but sometimes toothed
      k. Base of leaf-blade oblique; leaf elm-like in appearance (hackberry) Genus 12. Celtis
      l. Base of leaf-blade symmetrical, not oblique
        m. Leaves with distinct sharp teeth; flowers and fruits in catkins (alders and birches)
          mm. Leaf margin doubly toothed; surface of leaf rough and coarse (alder) Genus 10. Alnus
          nn. Leaf margin with a single series of teeth; surface of leaf smooth (birch) Genus 9. Betula
        n. Leaves wavy, or with inconspicuous teeth
          o. Leaves less than one inch long; fruit feathery (mountain mahogany) Genus 13. Cercocarpus
          p. Leaves larger; fruit oval, with a thin wing all around (ash) Genus 19. Fraxinus

II. Trees with compound leaves, each of three or more leaflets
  Q. Leaflets rounded, thorns present (locust) Genus 17. Robinia
  R. Leaflets with pointed tips; no thorns present (box-elder) Genus 18. Acer

  Here also belongs the green ash Genus 19. Fraxinus

LIST OF DECIDUOUS TREES NATIVE TO COLORADO

Genus 7. POPULUS, Aspens, Poplars, Cottonwoods. Six species native to the State.

Genus 8. SALIX, Willows. About six species in the State are trees but there are other shrubby forms.

Genus 9. BETULA, Birches. Two tree species and one shrub.

Genus 10. ALNUS, Alder. One species in the State, a small tree.

Genus 11. QUERCUS, Oaks. About four species in the State have the form of trees. Besides these, there are some strictly shrubby forms.

Genus 12. CELTIS, Hackberry. Probably only one native species.

Genus 13. CERCOCARPUS, Mountain Mahogany. One or two species; shrubs or sometimes tree-like.

Genus 14. AMELANCHIER, Juneberry, Service-berry. One or two tree-like species and about four which are merely shrubs.

Genus 15. CRATAEGUS, Thornapple, Hawthorn. Six or more species of small trees or large shrubs.

Genus 16. PRUNUS, Plum, Cherry, Choke-cherry. Four species in the State. One of them is always a low shrub.

Genus 17. ROBINIA, Locust-tree. A single species, the pink locust, in southern Colorado.

Genus 18. ACER, Maple, Box-elder. One large shrub or small tree, the mountain maple, and one or two species of box-elder.

Genus 19. FRAXINUS, Ash. Represented in Colorado by one species in the western part of the State and by another, the green ash, in the Rocky Mountain National Park.

Note: Readers are reminded that the keys and lists of trees include only the species native to Colorado. Nearly all of the trees of the Eastern States will grow if planted and irrigated.

Appendix II

EARLY SPRING FLOWERS OF BOULDER AND VICINITY

Members of the botany classes of the University of Colorado have made a list of the early wild flowers. Only native plants are included,—no introduced weeds. Trees and shrubs also are not listed, nor are grasses. One sedge is named because of its great abundance. The list is not complete, but it gives a good idea of the plants which are likely to be found on the plains and in the mountain country around Boulder to about May 25. Plants are listed in the order in which they were reported.

1. Easter-daisy (Townsendia exscapa)
2. Whisk-broom parsley (Cogswellia orientalis)
3. Pasque-flower (Pulsatilla hirsutissima)
4. Blue violet (Viola canadensis)
5. Spring-beauty (Claytonia rosea)
6. Chickweed (Cerastium campestre)
7. Blue-eyed Mary (Collinsia parviflora)
8. Wild candytuft (Thlaspi coloradense)
9. Whitlow-grass (Draba coloradensis)
10. Chickweed (Alsine)
11. Microstere (Microsteris micrantha)
12. Sedge (Carex pennsylvanica)
13. Yellow violet (Viola nuttallii)
14. Double bladder-pod (Physaria didymocarpa)
15. Pale-blue violet (Viola rafinesquii)
16. Wood whitlow-grass (Draba nemorosa)
17. Sand lily (Leucocrium montanum)
18. Puccoon (Lithospermum linearifolium)
19. Ball cactus (Cactus viviparus)
20. Cinquefoil (Drymocallis glandulosa)
21. Golden pea (Thermopsis montana)
22. Dwarf loco (Aragallus multiceps minor)
23. Clover-like loco (Orophaca tridactylica)
24. Wild carrot (Musineon divaricatum)
25. Ground-plum (Geoprumnon crassicarpum)
26. Larkspur (Delphinium nelsonii)
27. Golden-smoke (Capnoides aureum)
28. False dandelion (Nothocalais cuspidata)
29. Smooth buttercup (Ranunculus glaberrimus)
30. Milk vetch (Tium drummondii)
31. Saxifrage (Micranthes rhomboidea)
32. Beggar's ticks (Lappula occidentalis)
33. Buttercup (Ranunculus ellipticus)
34. Tansey mustard (Sophia incisa)
35. Thelypod (Thelypodium sagittatum)
36. Wall flower (Cheirinia wheeleri)
37. Marsh pea or vetchling (Lathyrus leucanthus)
38. Purple Vetchling (Vicia)
39. White water-crowfoot (Batrachium flaccidum)
40. Bluebell (Mertensia lanceolata)
41. Wild blue flax (Linum lewisii)
42. Waterleaf (Hydrophyllum fendleri)
43. Cat's-paw (Antennaria rosea)
44. Bird-foot violet (Viola pedatifida)
45. Small-flowered gilia (Gilia inconspicua)
46. Death camas (Toxiscordion falcatum)
47. Pink phlox (Phlox multiflora)

48. Leather-flower (Viorna eriophora)
49. Spurge (Tithymalus robustus)
50. Rock cress (Arabis divaricarpa)
51. Bedstraw (Galium vaillantii)
52. Rock primrose (Androsace occidentalis)
53. Harbouria (Harbouria trachypleura)
54. False Solomon's-seal (Vagnera stellata)
55. Western blue violet (Viola cognata)
56. Slender beard-tongue (Pentstemon virens)
57. Wild blue flag (Iris missouriensis)
58. Cranesbill (Geranium caespitosum)
59. Shooting-star (Dodecatheon)
60. White loco (Oxytropis saximontana)
61. Colorado loco-weed (Oxytropis bilocularis)
62. Scarlet mallow (Sphaeralcea coccinea)
63. Ground-plum (Geoprumnon succulentum)
64. Mountain daisy (Erigeron flagellaris)
65. Pinnate gilia (Gilia pinnatifida)
66. White evening-primrose (Anogra coronopifolia)
67. Wild onion (Allium)
68. Miner's Candle (Oreocarya virgata)
69. Single bladderpod (Lesquerella montana)
70. Toadflax (Comandra pallida)
71. Blue toadflax (Linaria texana)
72. Vervain (Verbena)
73. Milk-vetch (Astragalus goniatus)
74. Beard-tongue (Pentstemon angustifolius)
75. Beard-tongue (Pentstemon secundiflorus)
76. Spiderwort (Tradescantia occidentalis)
77. Blue-eyed-grass (Sisyrinchium angustifolium)
78. Skull-cap (Scutellaria brittoni)
79. False Solomon's-seal (Vagnera amplexicaulis)
80. Slender loco (Homalobus flexuosus)
81. Scorpion-weed (Phacelia leucophylla)
82. Paint-brush (Castilleja sessiliflora)
83. Horse mint (Monarda pectinata)
84. Purple ground-cherry (Quincula lobata)
85. Turret Plant, Deer's-tongue (Tessaranthium)
86. Mountain Forget-me-not (Eritrichium argenteum)
87. Mountain cinquefoil (Potentilla concinna)
88. Monkey-flower (Mimulus langsdorfii)
89. Gaillardia (Gaillardia aristata)
90. Rock Primrose (Androsace pinetorum)
91. Globe-flower (Trollius albiflorus)
92. Alpine Phlox (Phlox caespitosa)
93. Stone-crop (Sedum stenopetalum)
94. Dogbane (Apocynum ambigens)
95. Harebell (Campanula petiolata)
96. Cancer-root (Thalesia)
97. Golden-aster (Chrysopsis villosa)
98. Gum-plant (Grindelia serrulata)
99. Sand-verbena (Abronia fragrans)
100. Annual lupine (Lupinus pusillus)
101. Sophora (Sophora sericea)
102. Rattle-weed (Astragalus ceramicus)

Appendix III

COLORADO VEGETATION STUDIES*

Bruderlin, Katharine, "A study of the lodgepole-pine forests of Boulder Park (Tolland, Colorado)" Univ. of Colo. Studies, 8: 265-275. 1911.

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Clements, F. E. "Formation and succession herbaria." University of Nebraska Studies, 4: 329-355. 1904.

............, Plant Physiology and Ecology, pp. 295. New York, 1907.

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............, Plant Succession, Washington, 1916.

Cooper, William S., "Alpine vegetation in the vicinity of Long's Peak, Colorado." Bot. Gaz., 45: 319-337. 1908.

Elder, Mary Esther, "Roadside plants of a high mountain park in Colorado." Torreya, 12: 175-180. 1912.

Fuller, George D., "A comparison of certain Rocky Mountain grasslands with the prairie of Illinois." Reprint (pp. 1-10) from Trans. Ill. Acad. Sci. Vol. 8. 1915.

Leonard, Helen A., "Aspen groves of Boulder Park, at Tolland, Colorado." Thesis for M. A. degree at University of Colorado (typewritten and bound, in Library). 1916.

McIntosh, Arthur C., "Vegetation at different elevations in Boulder Canyon." Thesis for M. A. degree at University of Colorado, (typewritten and bound, in Library). 1923.

Ramaley, Francis, "Remarks on the distribution of plants in Colorado east of the divide." Postelsia. 1901.

............, "Plants of the Florissant region in Colorado." Univ. of Colo. Studies, 2: 177-185. 1906.

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............, "European plants growing without cultivation in Colorado." Annales du Jardin Bot. de Buitenzorg. Ser. II, Suppl. III. 493-504. 1909.

............, "Remarks on some northern Colorado plant communities with special reference to Boulder Park, Tolland, Colorado." Univ. of Colo. Studies, 7: 223-236. 1910.

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............, "The relative importance of different species in a mountain grassland." Bot. Gaz., 60: 154-157. 1915.

............, "Dry grassland of a high mountain park in northern Colorado." Plant World, 19: 249-270. 1916.

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*This is a bibliography of vegetation studies; articles of taxonomic or geographic nature are not listed, nor are papers which deal with the ecology of individual plants.

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............, "Some mountain plant communities of sandy soil." Plant World, 22: 313-328. 1919.

............, "Sub-alpine lake-shore vegetation in north-central Colorado." Amer. Jour. Bot., 7: 57-74. 1920.

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Reed, E.L., "Meadow vegetation in the montane region of northern Colorado." Bull. Torr. Bot. Club. 44: 97-109. 1917.

Robbins, W. W., "Distribution of deciduous trees and shrubs on the mesas." Univ. of Colo. Studies, 6: 36-49. 1908.

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Robbins, W. W. and Dodds, G. S., "Distribution of conifers on the mesas." Univ. of Colo. Studies, 6: 37-49. 1908.

Schneider, Edward C., "The distribution of woody plants in the Pike's Peak region." Colorado College Publication, Science Series, 12: 137-170. 1909.

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Shantz, Homer L., "A study of the vegetation of the mesa region east of Pike's Peak." Bot. Gaz., 42: 16-47, 179-207. 1906.

............, "Natural vegetation as an indicator of the capabilities of land for crop production," U. S. Dept. Agric., Bur. of Plant Industry, Bull. No. 201. 1911.

............, "Plant succession on abandoned roads in eastern Colorado." Jour. of Ecology, 5: 19-42. 1917.

Schmoll, Hazel M., "Ecological botanical survey of the Chimney Rock area, Pagosa-Piedra region, Colorado, summer, 1924" (a report prepared for State Historical and Natural History Society of Colorado, as yet unpublished).

Vestal, Arthur G., "Prairie vegetation of a mountain front area in Colorado." Bot. Gaz., 58: 377-400. 1914.

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Weaver, John E., "Root development of field crops." New York, 1926.

Young, Robert T., "Forest formations of Boulder County, Colorado, Bot. Gaz., 44: 321-352. 1907.

Appendix IV

BOOKS ON BOTANY SUITABLE FOR HIGH-SCHOOL AND PUBLIC LIBRARIES IN COLORADO

Works on Botany in General:

Bailey: Cyclopedia of Horticulture (Macmillan) 1927, 3 vols.

Bailey: Manual of Cultivated Plants (Macmillan) 1924

Berry: Tree Ancestors (Williams & Wilkins Co.) 1923

Boerker: Our National Forests (Macmillan) 1920

Coulter Outline of Genetics (University of Chicago Press) 1923

Durand: Wild Flowers and Ferns in their Homes and in our Gardens (G. P. Putnam's Sons)

Gager: General Botany (Blakiston) 1926

Peirce: Physiology of Plants (Henry Holt & Co.) 1926

Robbins: Botany of Crop Plants (Blakiston) 1924

Robbins: Principles of Plant Growth (Wiley) 1927

Sargent: Manual of Trees of North America (Houghton, Mifflin) 1922

Sinnott: Botany, Principles and Problems (McGraw-Hill) 1923

Skeene: Biology of Flowering Plants (Macmillan) 1924

Transeau: General Botany (World Book Co.) 1925

Willis: Flowering Plants and Ferns (Cambridge University Press) 1908

The Nature Library: volumes on Wild Flowers, Grasses, Mosses and Lichens, (Doubleday, Page & Co.)

Note: This is a very brief list of important and useful works. Larger schools and larger libraries will need a much more extensive collection.

Works dealing Especially with Colorado:

Clements and Clements: Rocky Mountain Flowers (H. W. Wilson Co.) 1920

Coulter and Nelson: Manual of Rocky Mountain Botany (Amer. Book Co.) 1909

Longyear: Trees and Shrubs of the Rocky Mountain Region (Putnams) 1927

Ramaley: Check List of the Plants of University Camp Area. Pamphlet, 1923

Ramaley: Colorado Plant Life (Univ. of Colo.) 1927

Rydberg: Flora of the Rocky Mountains and Adjacent Plains (P. A. Rydberg, New York Botanical Gardens) 1917

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